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Red Clover Hays of Varying Phosphorous Content for Growing Beef Calves

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To the Graduate Council:

I am submitting herewith a thesis written by Ben Hall McFarlin entitled "Red Clover Hays of Varying Phosphorous Content for Growing Beef Calves." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

Henry Rankin Duncan, Major Professor

We have read this thesis and recommend its acceptance:

Dorothy Williams, Marshall Hervey

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

August 1, 1941

To the Committee on Graduate Study:

I am submitting to you a thesis written by Ben Hall McFarlin entitled, "A Study of Red Clover Hays of Varying Phosphorus Content for Growing Beef Calves." I recommend that it be accepted for twelve quarter hours credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Husbandry.

W. R. Duncan
Major Professor

We have read this thesis
and recommend its acceptance:

Dorothy E. Williams

Marshall O'Kelley

Accepted for the Committee

V. C. Smith
Dean of the Graduate School

A STUDY OF RED CLOVER HAYS OF VARYING PHOSPHORUS CONTENT FOR GROWING BEEF CALVES

A THESIS

Submitted to
The Committee on Graduate Study
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

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by

Ben Hall McFarlin

August 1941

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B. H. McF.

INTRODUCTION

The majority of the world supply of milk, meat, wool, and hides is drawn from animals whose principal food is roughage, either in the form of hay or pasture. The greater the production of these economically important products, the greater the mineral need, in addition to other needs, of the animals producing them. These mineral requirements constitute a phase of the science of nutrition which has only recently attained any degree of prominence.

Up until the close of the first decade of the present century, energy values and digestive nutrients were the general standards by which rations and diets were measured. The significance and value of many other factors either were not realized at all, or if realized were given only minor consideration. So far as inorganic constituents were concerned, the necessity for their presence in the ration was long ago recognized and their functions in the body studied; but the generally prevalent opinion was that a ration which met the requirements for energy and nutritive-ratio standards also supplied sufficient mineral matter. That there might be a time when the supply of mineral matter in the ration becomes a limiting factor in the well being of an animal was not fully realized.

Comparisons made by early workers of the ash ingredients of many rations showed much mineral matter to be present. Analytical work of this nature "tended to confirm the prevalent idea that rations adequate in other respects may be assumed to contain a sufficiency of ash ingredients".(1) As the analytical work became more detailed, and as more

was learned from experimental animals, it was conclusively proved that the above-mentioned belief was a mistaken one. In other words, a ration might be deficient in a mineral ingredient and still meet the quantity standards for energy values and nutritive ratios. Now, we realize that the mineral requirement question is of great economic importance, and much time has been devoted to educating the farmer as to the mineral needs of different farm animals.

It has been strikingly demonstrated that rations from different sources have a decidedly different biological value, regardless of how similar they may be with respect to digestible protein and net energy. What causes this difference, in many instances, is still a matter for research to solve.

The Tennessee Valley Authority is vitally interested in the effect of phosphorus on crop yields and the nutritional value of these crops on livestock. They manufacture different phosphatic fertilizers and test them on farms and in laboratories. Financial assistance is given by the Tennessee Valley Authority to the Tennessee Experiment Station in this study of the feeding value of clover hays of varying phosphorus contents for growing beef calves. This experiment was originated to (1) study the growth of calves fed rations differing only in the phosphorus content of the red clover hay; and (2) to study the availability to growing beef calves of the phosphorus in the red clover hays having a different phosphorus content.

It was thought that further study should be made before any definite conclusions could be drawn. The present experiment is a continuation of the previous year's work, with some additional phases.

REVIEW OF LITERATURE

The economic importance of phosphorus for livestock is very great. Sheets[3] thinks phosphorus deficiency is the most decisive factor in mineral nutrition in the South, and in other locations with low-phosphorus content of the soil and of plants. The 1939 YEARBOOK[4] in telling of the importance of phosphorus reads, "Until further experimental evidence is available on mineral requirements of beef cattle, it may be the best plan, with few exceptions, to consider calcium and phosphorus as the minerals which have a real economic relationship to the cattle industry." Dr. V. H. Melass[5] of Texas A. and M. in speaking of the financial side of minerals said, "Thousands of dollars--perhaps millions--are spent annually by stockmen for minerals to feed to their livestock. Much of this is invested wisely, some more or less unwisely, and some downright foolishly."

Weathers[6] and Mooers[4] from Tennessee; Sheets[3] from Mississippi; Schmidt[7] and Tash[8] from Texas; Walker[4] from Arizona; Horlacher[4] from Arkansas; Hart[4] from California; Newell[4] from Florida; Beeson[9] from Idaho; Forbes and Johnson[10] from Pennsylvania; Hart and colleagues[11] from Wisconsin; Armsby[1] from New York; Knox and Neale[12] from New Mexico; Bechtel and associates[13] from Michigan; Rupel[14] from Wisconsin; Archibald and Bennett[15] from Massachusetts; Hughes[4] from Kansas; Lush[4] from Louisiana; Eckles and Palmer[16] from Minnesota; Welch[17] from Montana; Loeffel[4] from Nebraska; Records[4] from Nevada; Ellenberger and associates[18] from Vermont;

Forbes and associates[19] from Ohio; Henderson and associates[20] from West Virginia; Ingraham[21] from Wyoming; Christensen[4] from North Dakota; Haag[4] from Oregon; Holdaway[4] from Virginia; Kisalsu Kitta[22] from Japan; Murphy[23] from Victoria, New South Wales, Tasmania, and New Zealand; Forbes[19] from Alaska; Carbery[24] from India; Theiler[25] from South Africa; Henry[26] from New South Wales;and Tuff[27] from Norway report either phosphorus deficiencies or low-phosphorus hays being grown in their respective territories.

Orr[27] refers to Camerarius' writing of the occurrence of pica on the farms in the Black Forest region of Europe, and also makes reference to the mineral deficiencies of the pastures on the British Isles.

This brief list of many important references to studies throughout the world leads us to the conclusion that the problem of phosphorus deficiency is a world-wide one.

Recent work has given us much information as to the phosphorus metabolism of animals. Tash[8] in some recent work with yearling heifers on the range in Texas found that those heifers that received a phosphorus supplement were worth nearly thirteen dollars more than the heifers that did not receive a supplement; also, of the cows under observation, only twenty-one percent produced calves for two consecutive years that did not receive a phosphorus supplement, and of the cows that did receive additional phosphorus, 72 percent. Forbes and Johnson[10] at Pennsylvania, Ellenberger and associates[28] at Vermont, Carbery[24] in India, Theiler and associates[29] in South Africa, and others also report breeding troubles with cows that do not receive sufficient phosphorus.

Reference is made to phosphorus deficiency diseases under the following names: "aphosphorosis", "Styfsiekte", and "osteophagia", by Theiler[25]; "osteomalacia" and "osteophorosis", by Maynard[30]; "alkali disease" and "Grand Traverse disease", by Forbes[19]; "Loin Disease" and "down-in-the-back" by Schmidt[7].

The typical physical symptoms of phosphorus deficiency among cattle in Australia are stiffness in the hindquarters, swelling in the joints, dull eyes, a harsh dry coat, unthrifty general appearance, perverted appetite, leg and rib bones easily broken (soft bones in some, brittle in others) as reported by Henry[26]. Theiler and associates[31] observed depraved appetite for bones, leather, and wood, as the principal symptom of phosphorus deficiency. They also observed that anorexia, or lack of eppetite for normal food, was associated with phosphorus deficiency, and that cattle under such conditions did not make good use of their feed. Tuff[32] made reference to paralysis as a common occurrence among animals suffering from a lack of phosphorus. These symptoms for aphosphorosis are in accord with the observations of Welch[17], Eckles and coworkers[33], Rupel[14], and Forbes and Johnson[10].

Preceding the physical symptoms of phosphorus deficiency is a lowering of the blood phosphorus content. Tash[8] found that blood analyses were of value in locating phosphorus-deficient areas and that 4 mgm. per 100 cubic centimeters of blood is considered to be evidence of a deficiency of phosphorus. Rupel[14] noted a decline in the level of inorganic blood serum phosphorus preceding the outward appearances of aphosphorosis. He concluded that approximately 7 mgm. of inorganic phosphorus might be considered normal for calves from one to ten months

of age. These reports of the decrease in blood phosphorus preceding the outward appearances of phosphorus deficiency agree with the reports by Theiler and associates[25], Forbes and associates[34], Beeson and associates[9], Sheets[3], and Huffman and associates[35].

Not only in cattle, but in other animals, a decrease is noted in the inorganic phosphorus content of the blood serum when suffering from rickets. Howland and Kramer[36], Hess and Unger[37], Hess and Lundazen[38], Von Meysenbug[39], György[40], Kramer and Howland[41], Gutman and Franz[42], and Pork[43] observed that the first noticeable signs of rickets in children and rats are probably a diminution of the inorganic phosphorus of the blood. Johnson[44], using the Youngburg and Youngburg method of analyzing blood samples taken from normal calves, observed a range in the inorganic phosphorus of the blood for calves one to seven months old to be 5.4 to 7.4 milligrams per 100 cc. and for calves eight to thirteen months old to be 5.2 to 7.1. It was noticeable that the inorganic phosphorus of the blood of immature cattle diminished with increase in age in an approximately regular manner.

That the study of phosphorus deficiency is no simple task is pointed out by Forbes and associates[45] when they say that

> the balances of the mineral nutrients are affected by such a complication of influences, solubility of compounds present, interaction of inorganic acids and basis in solution in the alimentary tract and in the blood, absorption from the alimentary tract, relation to carbohydrate and fat metabolism, utilization by synthesis in body tissues (especially as limited by the quantities of associated nutrients present), fluctuations in the nutrient reserves of the body, and elimination by kidneys and intestine-that it is impossible to interpret closely, and with assurance the differences in mineral balances resulting from differences in amounts and kinds of feed consumed.

The relationship of calcium to phosphorus is an important consideration in any mineral study. After considerable work with calcium and phosphorus metabolism of cows, the Michigan Agricultural Experiment Station(46) concludes that "the total intake of calcium or phosphorus has a greater significance in the utilization of these elements than has the calcium-phosphorus ratio in the food." This is in agreement with Theiler and coworkers(29) who believe that in any ration it is the percentage of phosphorus in relation to the total feeding value which is of importance in determining aphosphorosis. But this disagrees with Meigs and coworkers(47) who suggest that phosphorus assimilation may be interfered with by an excess of calcium in the ration and that two parts or more, by weight, of calcium to one of phosphorus constitutes an excess.

The amount of phosphorus required by a growing beef steer varies with the individual animal. Beeson and associates(9) at Idaho Experiment Station attempted to determine the phosphorus requirements of beef cattle using 450-pound Angus steers in their experimental work. They produced aphosphorosis by feeding a ration containing 0.12 percent phosphorus with an average daily intake of 8.23 grams of phosphorus per steer. The blood phosphorus level dropped from 6.71 mg. to 4.40 mg. per 100 cc. of blood plasma. They decided that the beef calf requires about 2 grams of phosphorus daily per 100 pounds of live weight, and that the minimum phosphorus requirement in the ration of fattening beef calves lies between a daily intake of 8.23 and 12.96 grams. Armsby(12) says that the total retention of phosphorus during growth by cattle during the first year is 8.14 grams, and the average daily retention per 1000

pounds live weight of cattle during the first year is 0.037 grams. Van Landingham and associates[48] believe that the phosphorus requirement depends upon the rate of skeletal growth as measured by the rate of gain in height at withers. This is in agreement with Huffman and associates[35] who think that the phosphorus requirement for growth probably depends on the rate of growth and not on the size of the individual. Bechtel and associates[7] studied the pathology of rickets and concluded that growth was an important modifying factor. Another factor is age, because younger calves develop more severe cases of rickets than older calves within a given period of time when maintained under similar conditions.

Aphosphorosis can be prevented or cured by feeding phosphorus supplements or by feeding feeds rich in phosphorus. The experience of Beeson and associates[9] with the different forms of phosphorus was that an organic form of phosphorus, as is present in cottonseed meal, is not as available to the beef animal as an inorganic form (bonemeal). Krieger and coworkers after extensive research stated that, "In no case was the utilization of phosphorus from phytic acid equal to that of inorganic phosphorus." Maynard[30] says that "Half or more of the phosphorus of mature cereal seeds and their products, notably wheat bran, is present as phytin." The unavailability of the phosphorus in cereals helps to clarify the reason why some farm animals fed cereal by-products suffer from rickets and aphosphorosis. Schmidt[7] recommends the feeding of sweet bonemeal daily at the rate of about three ounces, mixed with salt, to prevent bone chewing of range cattle. He found that finely-ground rock phosphate did not give satisfactory results. Forbes and Johnson[10] concluded that the addition of bonemeal "ad libitum" to the rations of the

phosphorus-deficient cattle and horses produced prompt and marked improvement in the general health and blood phosphorus level. Knox and Neale(12) found that consumption of .134 ounces of phosphorus in the form of monocalcium phosphate was as effective in the curing and prevention of aphosphorosis as the consumption of larger amounts.

Another way of preventing or curing phosphorus deficiency is suggested by Murphy(23). He relates that on the Mornington Peninsula of Victoria it was impossible to maintain cattle in good condition on the natural vegetation until the composition was improved by fertilization with mineral and animal fertilizers. This is in agreement with Kisaku Kitta(22) and others who believe that differences in the composition of the soils affect the composition of the grasses grown thereon.

Rupel(14) suggests that sun exposure of six to eight hours during the summer months fully protects a calf on grass from rickets. He found the inorganic phosphorus of the blood of calves previously made richitic was increased by the addition of oxidized cod liver oil to the basal ration.

Bethke and associates(49) fed some rats at different levels of nutrition. They observed that with casein as the chief protein, and fed at the rate of 18 percent of the entire ration, the phosphorus requirements of the rat appeared to be supplied, because the addition of a neutral mixture of sodium and potassium phosphates did not lead to increased growth. This was also borne out in the normal composition of the blood and bones.

Having discussed some concentrates and mineral supplements that help prevent or cure rickets, we are ready to report some of the findings on roughages.

Forbes and Johnson(10) concluded that where phosphorus deficiency

did occur in Pennsylvania that it was caused by the exclusive feeding of roughages such as cereal straw and corn stover. Carbery(24) found that the lime requirement of Bengal cattle, under rice straw feeding, appeared to be higher than with many other feeds.

Krauss(50) recommends legumes as a fair source of phosphorus. The extent to which additional mineral feeding is necessary depends largely upon the degree to which legumes are utilized. But many times when legume hay is fed, he believes that there may be a shortage of phosphorus. Phosphorus deficiencies may occur when little or no grain is fed, when the grain mixture consists of corn and oats only, or when pasture furnishes the only feed. A mineral supplement can be used to supply the extra phosphorus, especially for animals that do not need the extra protein. Forbes(45) and coworkers found that a two-year-old steer would maintain equilibrium of phosphorus and nitrogen on an energy maintenance ration of corn meal and alfalfa hay in equal parts. In their experimental work, they had more phosphorus utilized from a maintenance ration of alfalfa hay than from the ration of corn meal and alfalfa hay. This agrees with the reports of experimental work by Hart and associates(51).

Williams(52,53)and associates in experimental tests with white rats fed lespedeza sericea, alfalfa, soybean, and red clover hays, found that the retention of food phosphorus was materially higher from the high-phosphorus hay ration than fromthe low-phosphorus hay ration. The same amount of phosphorus (0.16 peroent, minimum level for adequacy) was fed to each group. All other nutrients that were needed for proper growth were provided and the only known variable was the source of phosphorus.

The above-mentioned difference in the retention of food phosphorus was apparently due to a lack of absorption from the low-phosphorus hays which were fed in larger quantities than the high-phosphorus hays, in order to secure the same amount of phosphorus. Archibald and Bennett(15) in work with dairy heifers found that the retention of phosphorus per unit of weight was somewhat greater in high-phosphorus hays, but that the utilization of phosphorus was significantly greater in the low-phosphorus group. They concluded that hays containing 0.20 percent of phosphorus and consumed in normal amounts would supply sufficient phosphorus for normal growth, but below this percentage of phosphorus the hays would not supply the needed amount of phosphorus. In a thesis by Bible(54) on "The Value and Availability of the Phosphorus in a High-Phosphorus and a Low-Phosphorus Red Clover Hay to Growing Beef Cattle", it was concluded that, "the animals receiving the high-phosphorus red clover hay (.31% P.) made better use of their feed, maintained a higher blood phosphorus, and a thriftier condition, as evidenced by making greater gains and more growth, than the animals receiving the low-phosphorus hay (.12%P.)

PROCEDURE

Selection of Hays

The two red clover hays used in this experiment were as similar in quality and texture as possible, yet varying in their phosphorus content. Fourteen hay samples were taken from twelve farms located in East and Middle Tennessee and analyzed for their phosphorus content. The percent phosphorus in these hays is shown in Table I. The name represents the owner of the farm from which the sample was taken.

The phosphorus content varied from 0.14 to 0.24 percent, a difference of 0.10 percent. The range for the previous year's work was from 0.10 to 0.31 percent phosphorus. It is quite possible that the difference in rainfall or other factors for the two years account for why we were unable to get samples of hay in 1940 of as low a phosphorus content as the hays of 1939. The average was 0.19 percent for the fourteen samples and 0.01 percent higher than the average of the samples collected the previous year. Seven of the samples fall below the average figure in their phosphorus content. Samples of hay grown in East Tennessee were generally lower in their phosphorus content than the samples of hay grown in Middle Tennessee where the soil generally is richer in natural phosphorus.

The 0.16-percent hay produced by Mr. Henderson in Sevier County was used as the low-phosphorus hay, although in reality it was only slightly below the average of 0.18 percent given by Morrison(55) for red clover. It was fairly coarse but free from foreign material. This hay

TABLE I.

ANALYSIS OF CLOVER HAY SAMPLED 1940

Name	Phosphorus content (percent)	Post office	County
Dagland	0.14	Strawplaines	Jefferson
Henderson	0.16	Sevierville	Sevier
Sharp	0.16	Seymour	Blount
Turner	0.16	Eagleville	Rutherford
Jackson	0.16	Eagleville	Rutherford
U. T.	0.18,0.18,0.210	Knoxville	Knox
Neergaard	0.19	Kingston	Roane
Moore	0.20	Lenoir City	Roane
Hall	0.21	Arrington	Williamson
Borger	0.21	Harriman	Roane
Hay	0.26	Eagleville	Rutherford
Brandon	0.24	Lynchburg	Moore

contained 0.04 percent more phosphorus that the low-phosphorus hay used by Bible(54).

Difficulty was encountered in locating a large enough quantity of high-phosphorus hay. Finally, the 0.24-percent phosphorus hay grown by Mr. Brandon at Lynchburg in Moore County was selected and bought. This 0.24-percent phosphorus hay lacked 0.07 percent of having as high a percentage of phosphorus as the high-phosphorus hay used the previous year.(54) When received, this hay was somewhat disappointing because it was not of as good a quality as the sample received. Although it was not as coarse as the Sevier County hay, it contained considerable foreign material in the form of cornstalks (most of which were picked out before grinding), ryegrass, and weeds. Both hays were cut at about the same stage of maturity and were sweet and free from damage.

Samples were taken and analysis made of the soil on which each hay was grown. The results of this study are presented in Table II. This information shown in this table shows that the soil on which the 0.24-percent phosphorus hay was grown had more than twice as much available P_2O_5 per acre as the soil on which the 0.16-percent phosphorus hay was produced. The difference in available potash per acre is insignificant. Biological tests on the two soils reveal the increase in yield to be 120 percent with the Sevier County soil following an application of 200 pounds per acre of 16-percent superphosphate. The increase was only 40 percent with the Moore County soil.

As complete a history as possible was obtained of the previous management practices of the two fields from which the hay and soil samples were taken.

TABLE II

ANALYSIS OF THE SOIL ON WHICH THE EXPERIMENTAL HAY WAS GROWN

Soil sample	Description	Beckman pH	Phosphate				Potash			
			Available per A. (lbs.)	Rating	Increase rating	Inc. Per-cent	Available per A. (lbs.)	Rating	Inc. rating	Inc. per-cent
Brandon--Moore County (Soil on which high-phosphorus hay was produced)	No. 1 surface soil	5.6	156	High	Low	44	164	Low	High	66
"	No. 1 subsoil	5.7	194	Very high	Low	22	149	Very low	high	67
Moore County	No. 2 surface soil	5.0	167	High	Very low	14	146	Very low	High	76
" "	No. 2 subsoil	5.2	130	Medium	Low	32	120	Very low	Very high	91
" "	No. 3 surface soil	5.1	70	Low	High	94	182	Low	Medium	46
" "	No. 3 subsoil	5.4	137	High	Low	31	176	Low	Low	29
Average		5.3	142	High	Low	40	156	Low	High	62
*Henderson-Sevier Co. (soil on which average phos. hay was produced)	No. 1 surface	5.1	65	Low	High	120	150	Low	High	70

*Only one soil sample taken.

In 1795 an Englishman bought Buckingham Island, where the low-phosphorus hay was produced, for a saddle horse and a rifle. A house was built on the island and the land was put into cultivation. It was bought in 1930 by Mr. Hugh Henderson. A three-year rotation of corn, wheat, and clover has been used. The wheat yields have been about 16 bushels to the acre. The soil type is Congaree. In the fall of 1938, two hundred pounds of 20-percent superphosphate per acre was used on the wheat when it was sown. In the spring of 1939, clover was seeded in the wheat. The nineteen acres in this field yielded fifty loads of hay in the spring of 1940, or an estimated yield of about two and one fourth tons per acre. The second crop yielded fifty bushels of clover seed. This hay, therefore, was produced from productive land in a good state of cultivation.

The Moore County red clover hay was produced on soil typed as Etowah silt loam. The field is a creek bottom with a slope of from two to three percent. The information on management practices is quite incomplete. It is known that in 1926 a crop of crimson clover was turned under and that corn on this field in 1930 averaged 73 bushels per acre. In the fall of 1938, rye was seeded in the corn and the following spring red clover was seeded in the rye. The rye was pastured and yielded about 8 or 9 bushels to the acre. Applications of manure were made on the poorest spots in 1939. The high-phosphorus hay was cut in the spring of 1940, but the yield is unknown.

Experimental Animals

Fourteen grade calves of beef type were purchased from the auction market at Knoxville. Two of the most undesirable calves were culled out

and sold at the end of the preliminary period. The animals were as uniform in age (about six months old), size (average, 285 pounds), condition, and grade as was possible to obtain at that time. The animals were put on a preliminary ration of two parts alfalfa meal, one part beet pulp, and one part cornmeal. The phosphorus content of the feeds used in the preliminary ration is shown in Table III.

Many of the calves had to learn to eat dry feed. They were kept on this preliminary ration for 35 days to give them time to become adjusted to their new surroundings. Calves 197, 198, 199, 200, 722, 724, 725, and 716 were castrated during this period, the other calves having already been castrated.

All animals were groomed at frequent intervals to keep their skin in a healthy condition.

During the preliminary period, the animals were divided into ten lots and identification tags were placed in their ears. Table IV shows weight, grade, and condition of each calf at the beginning of the experiment. Individual feed troughs were provided for each calf, with chains attached, in order that the calves could be securely fastened during each feeding. The calves were placed in uniform stalls about 10 x 12 feet, located in the lower side of Temple Hall. Two calves were placed in each stall. Water was available in each stall at all times. The calves were fed twice a day at regular hours and given about one and one half hours in which to eat.

The feed consumption is shown in Tables VIII, XII, XVI, XX, XXIV, XXVIII, and XXXII. The hay was ground in a hammer mill on the University Farm. All rations were thoroughly mixed before being fed to the experi-

TABLE III

PRELIMINARY RATION[a]

Feed	Per-cent in ration	Total dry matter	Digest-ible protein	Total digest-ible nu-trients	Phos-phor-us[b]
		%	%	%	%
Alfalfa meal	50	92.4	5.9	43.0	0.17
Beet pulp	25	91.8	6.1	74.3	0.07
Corn meal	25	89.2	7.6	84.2	0.32

(a) Morrison's FEEDS AND FEEDING(55)
(b) Dr. D. E. Williams(56)

TABLE IV

CONDITION, WEIGHT, AND GRADE OF CALVES BY LOTS AT THE BEGINNING OF THE EXPERIMENT
(10-4-40)

Lot No.	Calf No.	Weight (pounds)	Feeder grade	Condition
I	200	258	Low good	Low medium
I	723	360	Medium	Medium
II	725	335	High medium	Medium
II*	198	277	Low medium	Fair
III	197	282	Good	Medium
IV	717	283	Medium	Medium plus
V	722	319	Low medium	Low medium
VI	718	309	Good	High medium
VII	721	331	Low good	Low good
VIII	724	322	Low good	Medium
IX	199	289	Low good	Medium
X	716	290	Medium	Low medium

*Calf 198 was started in Lot II and then removed after 140 days because he was not making any gains in weight.

mental calves. At each feed mixing, samples of the rations were taken for chemical analysis.

Wood shavings were used for bedding.

Attention was paid to the peculiarities and characteristics of each calf and these observations were carefully recorded.

Rations

The rations as planned for the 1940-41 trials are shown in Table V.

Significance of Rations

In the previous year's work, the high-phosphorus ration produced results in its favor, as judged from the calf gains. Also, the gains of calves on rations that contained casein were somewhat superior to those that did not. The experiments this year were planned to check the results of last year and to discover the underlying causes of the performance observed. Therefore, the following rations were compared:

Rations 1 and 2 were designed to test the ability of two red clover hays of widely differing phosphorus content to promote growth.

Phosphorus supplements were added to form rations 3 and 4, the quantity of supplement being determined by the amount necessary to make Ration 1 equal to Ration 2 in phosphorus content.

The effects of two different protein supplements are studied in Rations 5, 6, 7, 8, 9, and 10. Cottonseed meal is used as the protein supplement in rations 5 and 6, and casein is used as the protein supplement in Rations 7, 8, 9, and 10. The simultaneous addition of both a phosphorus and a protein supplement is studied in Rations 9 and 10.

Each ration meets the feed requirements of Morrison(55) for a growing, 300-pound beef calf, as regards total amount of feed, dry matter,

TABLE V

RATIONS USED IN PHOSPHORUS FEEDING EXPERIMENT 1940-41

Feed	Per cent	Amount	Dry matter	Digestible protein	Total digestible nutrients	Nutritive ratio	Fiber	Ca	P	Ca/P	Per cent P
Requirements for 300-pound calf		(lbs.)[a] 8.0	(lbs.[a]) 7.0-8.3	(lbs.[a]) .52-.58	(lbs.[a]) 3.9-4.6	1:[a] 6.5-7.0	(lbs.[a])	(gms.[b]) 15.1	(gms.[b]) 12.3	(b) 1.2	
RATION NO. 1 (av. P. Hay)											
Red clover (.16%P)	74.25	5.94	5.24	0.42	3.08		1.5	34.8	4.3		
Ground corn	24.25	1.94	1.65	0.14	1.56			0.1	2.8		
Salt	1.00	.08	.08								
Cod liver oil	0.50	.04			0.04						
TOTALS	100.00	8.00	6.97	0.56	4.68	7.4	1.5	34.9	7.1	4.9	.20
RATION 2. (High P. hay)											
Red clover(.24%P)	74.25	5.94	5.24	0.42	3.08		1.5	50.6	6.5		
Ground corn	24.25	1.94	1.65	0.14	1.56			0.1	2.8		
Salt	1.00	.08	.08								
Cod liver oil	0.50	.04			0.04						
TOTALS	100.00	8.00	6.75	0.56	4.68	7.4	1.5	50.7	9.3	5.5	.26

(continued)

(a) Morrison(55)
(b) Mitchell and McClure(57)

Table V. (continued)

	Per cent	Amt.	D.M.	D.P.	T.D.N.	N.R.	Fiber	Ca	P	Ca/P	Per cent P
RATION NO. 3 (No. 1 plus P)											
Red clover (.16%P)	74.25	5.94	5.24	0.42	3.08		1.5	34.8	4.3		
Ground corn	24.00	1.92	1.64	0.14	1.55		--	0.1	2.7		
Salt	1.00	.08	.08								
Cod liver oil	.50	.04			0.04						
CaH Po_4	.25	.02	.02					3.2	2.3		
TOTALS	100.00	8.00	6.98	0.56	4.67	7.3	1.5	38.1	9.3	4.1	.26
RATION NO. 4 (No. 2 plus P)											
Red clover (.24%P)	74.25	5.94	5.24	0.42	3.08		1.5	50.6	6.5		
Ground corn	24.00	1.92	1.64	0.14	1.55			0.1	2.7		
Salt	1.00	.08	.08								
Cod liver oil	.50	.04			0.04						
CaH Po4	.25	.02	.02					3.2	2.3		
TOTALS	100.00	8.00	6.98	.56	4.67	7.3	1.5	53.9	11.5	4.7	.32
RATION NO. 5 (No. 1 plus cottonseed meal)											
Red clover (.16%P)	66.0	5.28	4.66	0.37	2.74		1.4	30.9	3.8		
Cornstarch	20.0	1.60	1.44		1.44						
Beet pulp	5.0	.40	.37	0.02	0.30		0.1	1.0	0.1		
Cottonseed meal	7.5	.60	.56	0.20	0.44		0.1	0.5	3.2		
Salt	1.0	.08	.08								
C.L.O.	0.5	.04			0.04						
TOTALS	100.00	8.00	7.11	0.59	4.96	7.4	1.6	32.4	7.1	4.6	.20

(continued)

Table V (continued)

	Per cent	Amt.	D.M.	D.P.	T.D.N.	N.R.	Fiber	Ca	P	Ca/P	Per cent P
RATION NO. 6 (No. 2 plus cottonseed meal)											
Red clover hay(.24%P)	66.0	5.28	4.66	0.37	2.74		1.3	44.9	5.8		
Cornstarch	20.0	1.60	1.44		1.44						
Beet pulp	5.0	.40	.37	0.02	0.30		0.1	1.0	0.1		
Cottonseed meal	7.5	.60	.56	0.20	0.44		0.1	0.5	3.2		
Salt	1.0	.08	.08								
Cod liver oil	0.5	.04			0.04						
TOTALS	100.0	8.00	7.11	.59	4.96	7.4	1.5	46.4	9.1	5.1	.25
RATION NO. 7 (No. 1 plus casein)											
Red clover (16%P)	65.0	5.20	4.59	.36	2.70		1.3	30.5	3.7		
Cornstarch	25.5	2.04	1.84		1.84						
Beet pulp	5.0	.40	.37	.02	.30		0.1	1.0	0.1		
Casein	3.0	.24	.22	.21	.21			1.6	1.2		
Salt	1.0	.08	.08								
Cod liver oil	0.5	.04			.04						
TOTALS	100.0	8.00	7.10	.59	5.09	7.6	1.4	33.1	5.0	6.6	.14
RATION NO. 8 (No. 2 plus casein)											
Red clover (.24%P)	65.0	5.20	4.59	.36	2.70		1.3	44.3	5.7		
Cornstarch	25.5	2.04	1.84		1.84						
Beet pulp	5.0	.40	.37	.02	.30		0.1	1.0	0.1		
Casein	3.0	.24	.22	.21	.21			1.6	1.2		
Salt	1.0	.08	.08								
Cod liver oil	0.5	.04			.04						
TOTALS	100.0	8.00	7.10	.59	5.09	7.6	1.4	46.9	7.0	6.7	.19

(continued)

Table V. (continued)

	Per cent	Amt.	D.M.	D.P.	T.D.N.	N.R.	Fiber	Ca	P	Ca/P	Per cent P
RATION NO. 9 (No. 1 plus casein plus P)											
Red clover (.16%P)	65.0	5.20	4.59	.36	2.70		1.3	30.5	3.7		
Cornstarch	25.5	2.02	1.82		1.82						
Beet pulp	5.0	.40	.37	.02	.30		0.1	1.0	0.1		
Casein	3.0	.24	.22	.21	.21			1.6	1.2		
Salt	1.0	.08	.08								
Cod liver oil	0.5	.04			.04						
Ca H Po_4	0.25	.02						3.2	2.3		
TOTALS	100.00	8.00	7.08	.59	5.07	7.6	1.4	36.3	7.3	5.0	.20
RATION NO. 10 (No. 2 plus P plus casein)											
Red clover (.24%P)	65.0	5.20	4.59	.36	2.70		1.3	44.3	5.7		
Cornstarch	25.25	2.02	1.82		1.82						
Beet pulp	5.0	.40	.37	.02	.30		0.1	1.0	0.1		
Casein	3.0	.24	.22	.21	.21			1.6	1.2		
Salt	1.0	.08	.08								
Cod liver oil	0.5	.04			.04						
Ca H Po_4	0.25	.02						3.2	2.3		
TOTALS	100.00	8.00	7.08	.59	5.07	7.6	1.4	50.1	9.3	5.4	.26

digestible protein, and total digestible nutrients. The nutritive ratios and calcium content are above the recommended standards. Beeson and associates[9] at Idaho decided that the minimum phosphorus requirements in the rations of fattening beef calves lie between a daily intake of 8.23 and 12.96 grams. Jacob, Duncan, Williams, Morrell and Bible[54] at Tennessee found 7.5 grams to barely meet the phosphorus requirements under the conditions of their experiment for growing beef calves. Rations 1, 5, 7, 8, and 9 fall below the minimum range suggested by Beeson and Rations 2, 3, 4, 6, and 10 barely reach the suggested range. Ration 4 supplies the largest quantity of phosphorus (11.5 grams) of any ration. Ration 7, designated as the control, supplies the least amount of phosphorus (5 grams). Under these conditions a lack of availability of phosphorus for any cause whatsoever might easily put the total level of available phosphorus below the minimal requirements of the calves. The amount of cottonseed meal in Rations 5 and 6 was the quantity necessary to supply the same amount of protein as supplied by the casein in Rations 7, 8, 9, and 10. This means that in Rations 5 and 6, from 1/3 to 1/2 of the total phosphorus came from the cottonseed meal.

With the calcium requirements being more than adequately met and the phosphorus requirement barely met, or not met, it is natural that the calcium-phosphorus ratios should be high. Ration 3, with a calcium-phosphorus ratio of 4.1:1, more nearly approaches the ratio of 1:2.1 recommended by Morrison[55]; while Ration 8, with a ratio of 6.7:1, is the furtherest fromthe standard. The difference in the total amount of phosphorus between Rations 1 and 2, 3 and 4, 5 and 6, 7 and 8, and 9 and 10 is due to the difference in the phosphorus content of the two

hays. The composition of the ingredients used in the rations is given in Table VI.

Criteria for Judging Results

Body Measurements and Weights. Body measurements and weights were taken every twenty-eight days on three consecutive days. The measurements were made of the circumference of the heart girth and height at the withers. The average figure for the three days was taken as the representative weight or measurement for that twenty-eight-day period. These weights and measurements were taken as nearly as possible at the same time each day throughout the experiment.

Blood Analysis. Blood analyses were made for inorganic phosphate and calcium by the Youngburg and Youngburg method and the Clark and Collip method respectively. The blood samples were taken every twenty-eight days on the first and last day of the three-day consecutive period in which weights and body measurements were taken. Blood phosphorus analyses were made previous to putting the animals on the experimental ration and at regular intervals during the experiment. Blood calcium analyses were made previous to putting the animals on the experimental ration and several times during the experiment.

Pictures and observations. Pictures of each calf were taken at the start of the experiment, about half way through the experiment, and at the end of the experiment. As during the previous year, a charted background using six-inch squares was used. This background enabled one to observe the growth of the calves.

Close observation was kept for the entire experiment of any unusual characteristic or habit of the calves. These observations, along with

TABLE VI.

COMPOSITION OF RATION CONSTITUENTS

Feeding stuff	Total dry matter[a] (%)	Digestible proteins[a]	Total digestible nutrients[a]	Nutritive ratio 1:
Alfalfa meal (good)	91.9	10.8	53.9	4.0
Beet pulp (molasses	91.8	6.1	74.3	11.2
Casein	92.0[b]	86.3[c]	86.3	--
Clover, red (all analyses)	88.2	7.0	51.9	6.4
Corn, ground (No. 2 grade)	85.2	7.1	80.6	10.3
Cornstarch (Sherman Food Products)	90.0	--	90.0[d]	--
Cottonseed meal (41% protein)	92.8	33.9	73.6	1.2

a- Morrison's FEEDS AND FEEDING(55).
b- Moisture determination, Casein Company 7-5-39.
c- Moisture plus ash = about 11 percent. Therefore, percent protein = 89. Coefficient of digestibility of milk is 97 percent (Sherman Food Products, p. 97). Therefore, .97 x 89 = 86.3 percent digestible protein.
d- Raw cornstarch 100 percent digestible.

(continued)

TABLE VI. COMPOSITION OF RATION CONSTITUENTS (cont.)

	Protein		Fat		Fiber		N-free Ext.		Calcium		Phosphorus	
	Av. (a)	D.E.W. (b)	Av. (a)	D.E.W. (b)	Av. (a)	D.E.W. (b)	Av. (a)	D.E.W. (b)	Av. (a)	D.E.W. (b)	Av. (a)	D.E.W. (b)
Alfalfa meal	15.2	12.9	1.9	2.5	28.4	30.2	37.9	34.2	1.31	1.01	0.17	0.17
Beet pulp (molasses)	9.9	10.0	0.7	0.8	15.9	16.0	60.1	58.2	0.52	0.53	0.07	0.07
Casein	89.0								0.76	1.45	1.01	1.09
Clover, red (all anal.)	11.8	12.1(c) 10.9(d)	2.6	4.5 4.7	27.3	25.9 25.4	40.1	39.5 42.5	1.21	1.29 1.65	0.18	0.16 0.24
Corn, ground (no.2 grade)	9.4	8.6	3.9	4.8	2.2	2.5	68.4	70.7	0.01	trace	0.27	0.32
Cornstarch							90.0					
Cottonseed meal (41% prot.)	41.9		7.0		10.8		27.2		0.20		1.19	

(a) Morrison(55)
(b) Dorothy E. Williams(56)
(c) Average phosphorus red clover
(d) High phosphorus red clover

the date of their occurrence , were carefully recorded.

Results and Discussions

This experiment evolved itself into a comparison of Lots I and II, III and IV, IX and X, and the other calves as individual problems. The results and discussions are divided into the following parts:

Part I -- Lots I and II

Part II -- Lots III and IV

Part III-- Lots IX and X

Part IV -- Calves 722 and 718, i.e. Lots V and VI

Part V -- Calf 198

Part VI -- Calf 721

Part VII-- Calf 724 before being placed in Lot X

Part VIII-- Calf 716 after being removed from Lot X

Part IX -- Studies of the effects of adding phosphorus supplements for a supplementary period of 112 days

A deviation was made from the original feeding plan, for the following reasons:

1. Our supply of the high phosphorus hay was not sufficient to carry all lots.

2. Some calves did not give a normal response, and substitutions were considered wise.

PART I

RESULTS AND DISCUSSIONS OF LOTS I AND II

Rations 1 and 2 were designed to test the difference of two red clover hays of different phosphorus content to promote growth. Ration 1 contained 7.1 grams of phosphorus, and Ration 2, 9.3 grams. There were two calves on Ration 1 and one on Ration 2.

Weights and Body Measurements

The two calves in Lot I made quite different gains in heart girth and height, one calf, 200, gaining more than the calf in Lot II; and the other calf, 723, gaining less than the calf in Lot II in both respects. However, both calves in Lot I gained more than the calf in Lot II in body weight. For 252 days, Lot I averaged .68 of a pound a day gain in weight, while Lot II averaged over the same period .46 of a pound a day (Table VII).

Feed Consumed

Table VIII shows the amount of feed consumed during the preliminary period, and by twenty-eight-day periods, for the duration of the experiment. The feed consumption is some higher in Lot II than in Lot I. This was because of the smallness of one of the calves in Lot I, and its maintenance requirements for feed were not as much as the larger calf in Lot I (Calf 723). The feed consumption of calves 723 (Lot I), and 725 (Lot II) remained practically the same after the preliminary and first twenty-eight-day periods. The calves of Lot I made greater gains on less feed consumed on the average.

TABLE VII

AVERAGE GAIN IN HEART GIRTH, HEIGHT, AND WEIGHT OF LOTS I AND II, BY 28-DAY PERIODS

Period (28 days)	Gain in heart girth (inches)		Gain in height (inches)		Gain in weight (pounds)	
	Lot I (2 calves)	Lot II [a](Calf 725)[b]	Lot I (2 calv.)	Lot II [a](Calf 725)[b]	Lot I (2 calv.)	Lot II [a](Calf 725)[b]
1	0.21	0.42	0.21	0.25	21	15
2	0.83	0.25	0.67	0.50	27	19
3	0.47	0.58	0.38	0.75	6	1
4	0.25	0.75	0.83	1.17	12	19
5	0.96	0.58	0.50	0.08	14	0
6	1.21	0.84	0.46	0.50	28	18
7	1.21	0.08	0.96	1.00	24	8
8	0.79	0.92	0.70	0.17	19	19
9	0.82	0.75	0.46	0.91	22	18
Total	6.75	5.17	5.17	5.33	173	117
Average by periods	.75	.57	.57	.59	19.1	13
Average daily gain	.027	.02	.02	.021	.68	.46

(a) The gains for Lot I were the average of calves 200 and 723.
(b) Two calves were started in Lot II, but one calf did not make any gains and was unthrifty during the first 140 days; and for these reasons was removed from this lot. Therefore, the figures are for only one calf.

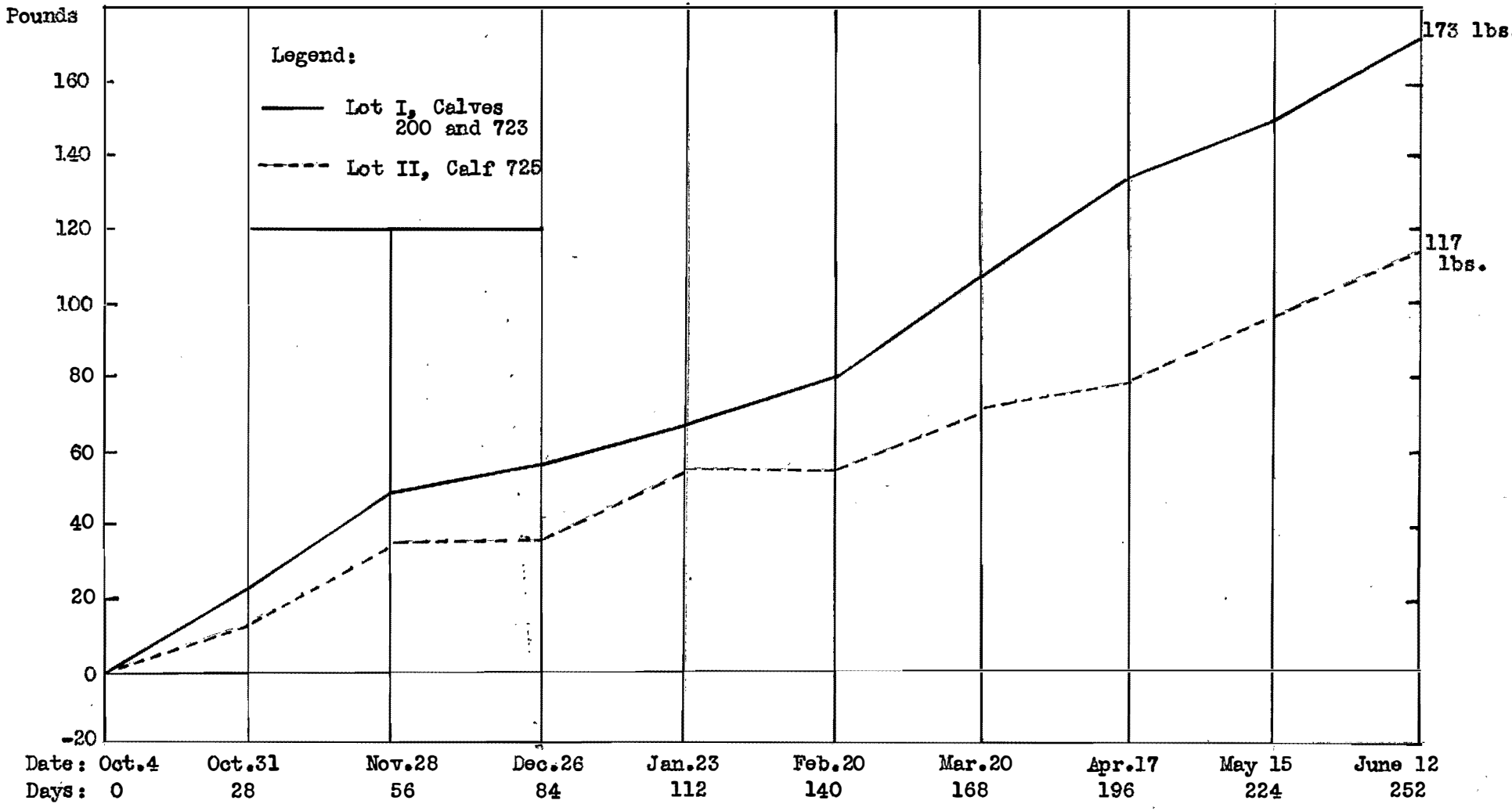


Figure 1. Average gain in weight of Lot and Lot II (Calf 725), by 28-day periods

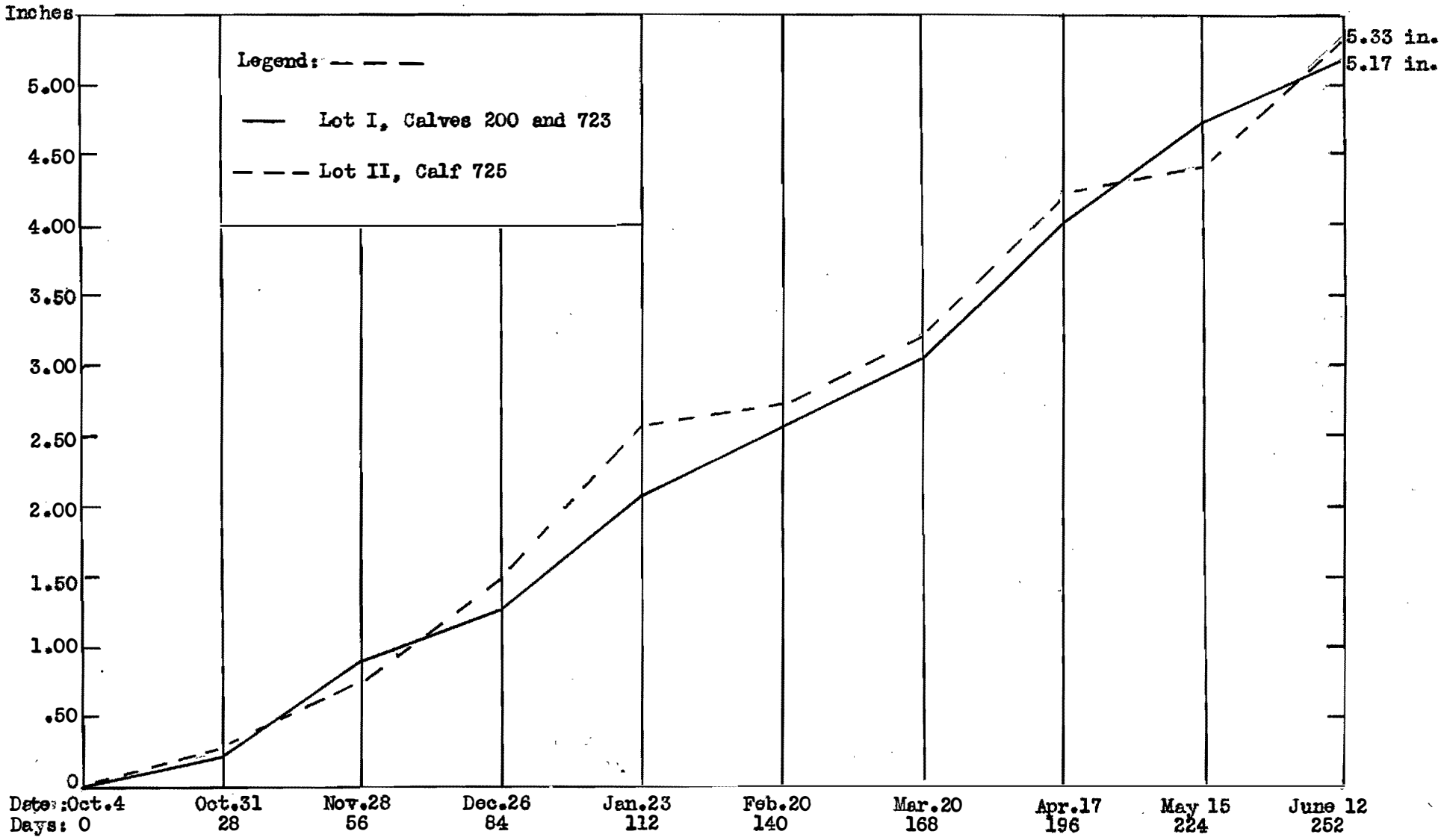


Figure 2. Average gain in height of Lots I and II (Calf 725) by 28-day periods

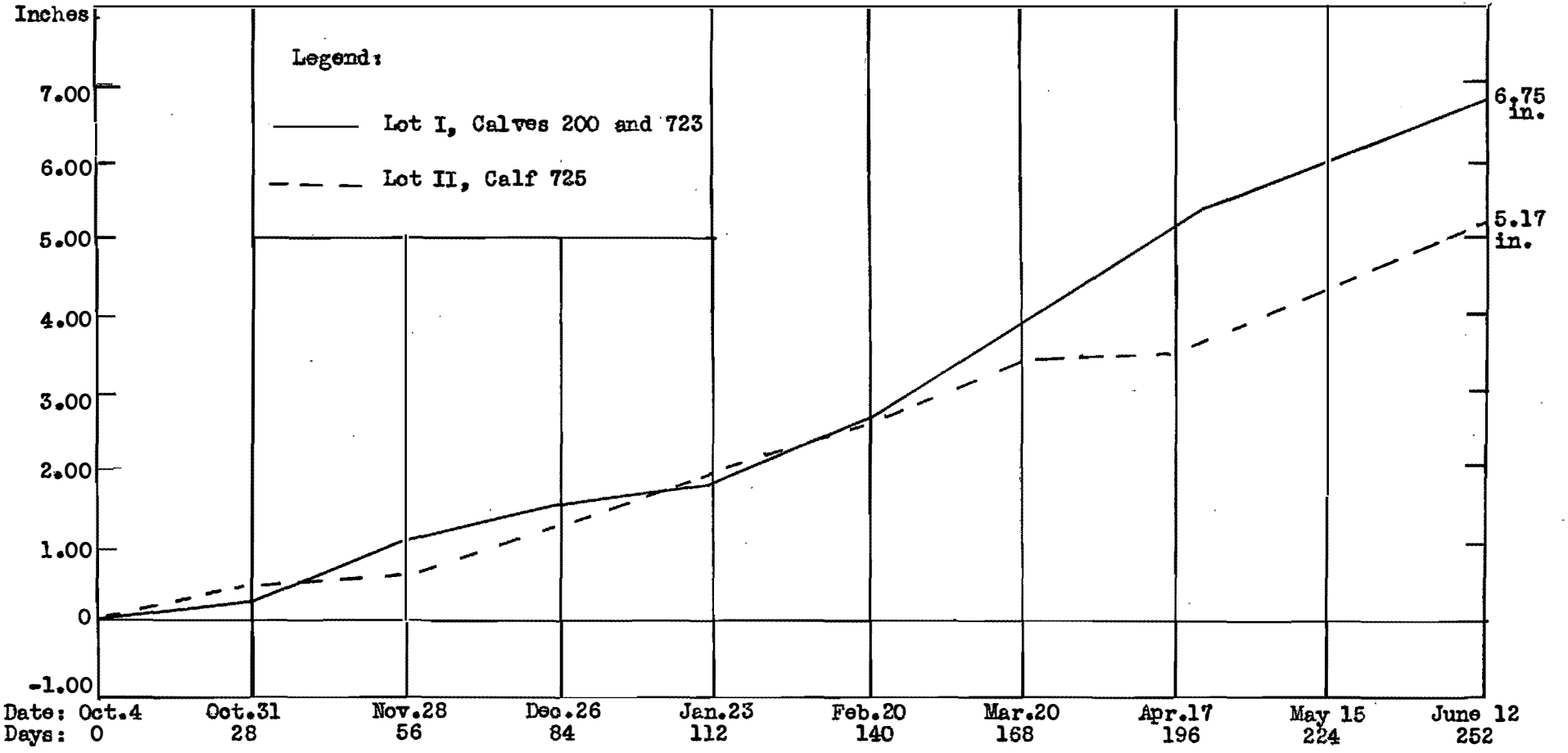


Figure 3. Average gain in heart girth of Lots I and II (Calf 725) by 28-day periods

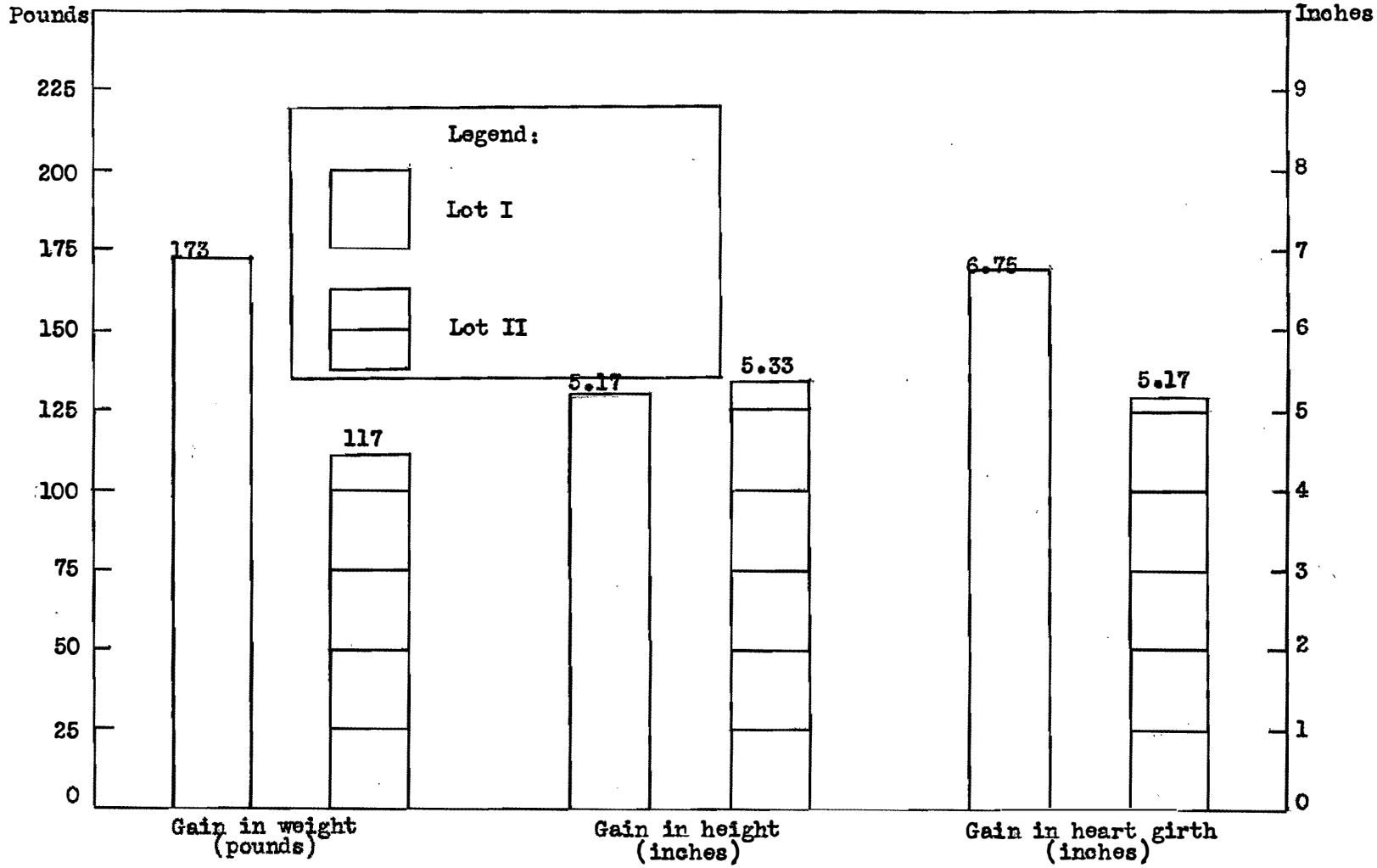


Figure 4. Gain in weight, height, and heart girth of Lots I and II

TABLE VIII

FEED CONSUMED IN PRELIMINARY AND 28-DAY PERIODS (POUNDS)

Lot No.	Calf No.	Prelimi-nary--35 days	1	2	3	4	5	6	7	8	9	Total last 9 periods
I	200	115.50	148.00	206.50	208.00	199.75	221.40	224.00	223.60	224.00	224.00	1879.25
I	723	153.25	173.25	234.50	238.00	238.00	238.00	238.00	238.00	238.00	238.00	2073.75
Total		268.75	321.25	441.00	446.00	437.75	459.40	462.00	461.60	462.00	462.00	3953.00
Average		134.37	160.62	220.50	223.00	218.87	229.70	231.00	230.80	231.00	231.00	219.61
Average daily consumption		3.83	5.74	7.87	7.96	7.82	8.20	8.25	8.24	8.25	8.25	7.84
II	725	136.98	176.75	234.50	238.00	238.00	238.00	238.00	238.00	238.00	238.00	2077.25
Average daily consumption		3.91	6.31	8.37	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.24

Blood Analyses

The feed consumption after the first 28-day period reached the maximum level, and for this reason the feed phosphorus consumption during the experiment was fairly uniform for each period. Lot I received an average of 7 grams of phosphorus a day, and Lot II received an average of 9.7 grams daily. Both lots maintained a relatively uniform blood phosphorus level during the experiment, that barely came within the normal range suggested by Johnson(44) of 5.4 to 7.4 mg. of inorganic phosphorus in 100 cc. of blood. The blood phosphorus analyses and feed phosphorus consumption are shown in Table IX.

The blood calcium average for Lots I and II differed very little. Table X shows the blood calcium analyses made at various times during the experiment

Pictures and Observations

Pictures of Lots I and II are on the following pages.

At the start of the experiment, calves in Lots I and II, as indicated by their general appearance, were in a thrifty and good growing condition. Calf 200 in Lot I evidently had been only on milk, for he was slow in starting to eat dry feed during the preliminary period. All calves ate the wood shavings that were used for bedding. As a general observation for the duration of the experiment, one would be safe in saying that the calves in both Lots I and II were in good physical shape during the entire experiment. Their appetites ranged from good to excellent and their fecal droppings were normal. Calf 725 in Lot II started eating wood shavings in a ravenous manner, as if seeking to satisfy his

TABLE IX

INORGANIC PHOSPHORUS OF THE BLOOD IN MG. PER 100CC. OF WHOLE BLOOD AND THE AVERAGE DAILY FEED PHOSPHORUS (GRAMS)

Lot No.	Calf No.	Days																					
		Beg.		28		56		84		112		140		168		196		224		252		Av.-Exp.	
		F(a)	B(b)	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B
I	200	3.1	3.19	5.3	5.70	6.4	5.84	6.6	5.22	6.3	5.99	7.0	5.28	7.1	5.31	7.1	5.75	7.1	5.51	7.1	5.41	6.6	5.55
	723	4.1	4.45	6.2	6.39	7.3	5.92	7.5	5.20	7.5	4.96	7.9	4.85	7.5	5.32	7.5	5.56	7.5	5.69	7.5	5.31	7.37	5.46
	Av.	3.6	3.82	5.7	6.05	6.8	5.88	7.1	5.21	6.9	5.48	7.5	5.07	7.3	5.32	7.3	5.66	7.3	5.60	7.3	5.36	6.98	5.50
II	725	3.7	3.59	8.2	5.64	9.6	5.67	9.9	5.89	9.9	5.70	10.3	4.88	9.9	5.53	9.9	5.82	9.9	5.37	9.9	5.90	9.7	5.60

(a) Feed phosphorus in grams.
(b) Blood phosphorus in mg.

TABLE X

BLOOD CALCIUM IN MG. PER 100 CC. OF BLOOD PLASMA

Lot No.	Calf No.	Periods during experiment				Average during experiment
		Preliminary	Beginning of exp.	112 days	196 days	
I	200	7.45	9.10	10.23	9.16	9.49
(Av. P)	723	7.45	10.51	9.21	9.44	9.72
	Av.	7.45	9.80	9.72	9.30	9.60
II (high P)	725	7.34	9.88	10.23	9.33	9.81

appetite after nearly 112 days on the experimental ration. He was not observed eating dirt or clay, but he did gnaw on his trough. After nearly 140 days, calves 723 and 200 were observed licking the dirt at the edge of their pen, and also eating their bedding of wood shavings. About the same time, they started gnawing on wood and as the experiment continued the gnawing gradually became worse. At the end of the experiment, the calves in Lots I and II continued to play about their stalls, indicating that they were feeling well. The calves in Lot I were in a little better flesh and their coat of hair was in better condition than the calf in Lot II at the end of the experiment.

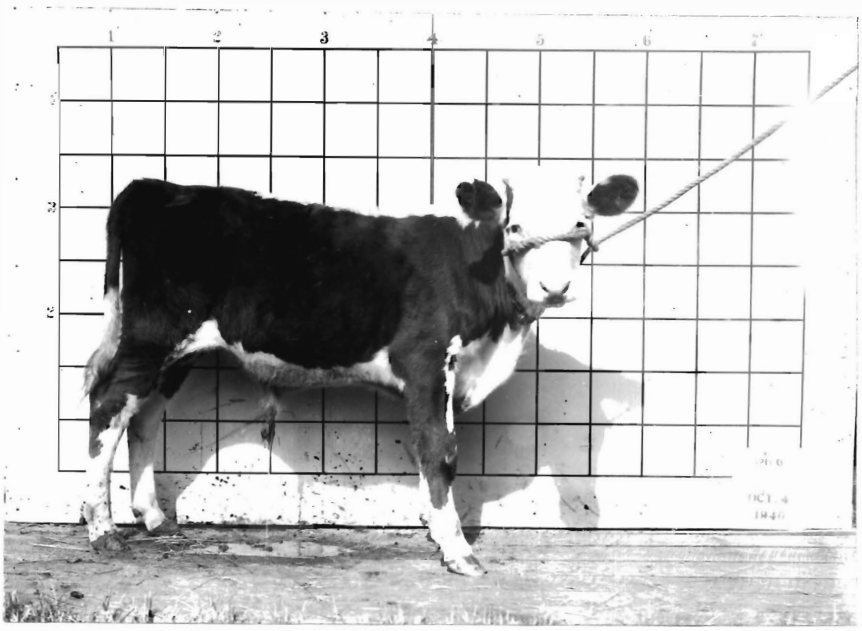


Figure 5. Calf 200 (Lot I) at the start of the experiment

Figure 6. Calf 200 (Lot I) after 112 days feeding

Figure 7. Calf 200 (Lot I) at end of experiment

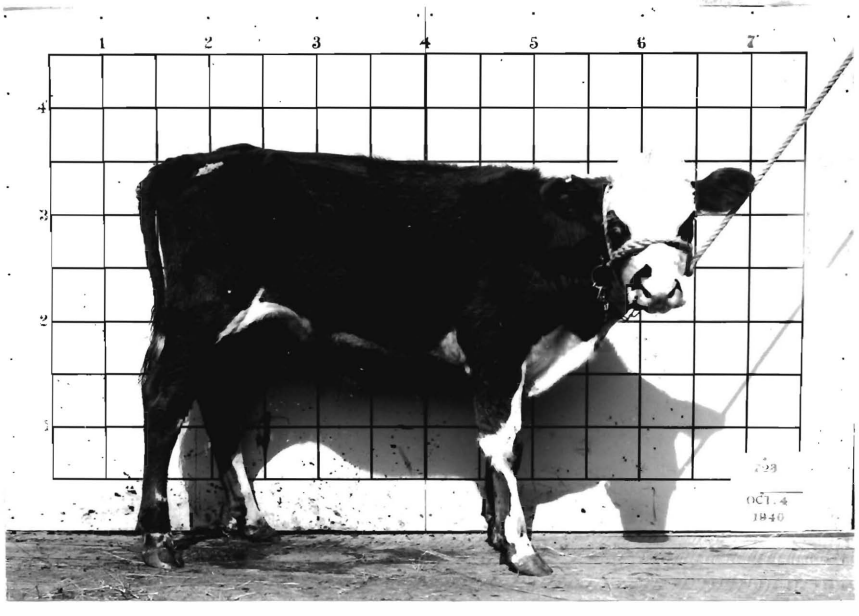


Figure 8. Calf 723 (Lot I) at start of the experiment

Figure 9, Calf 723 after 112 days feeding

Figure 10. Calf 723 (Lot I) at end of the experiment

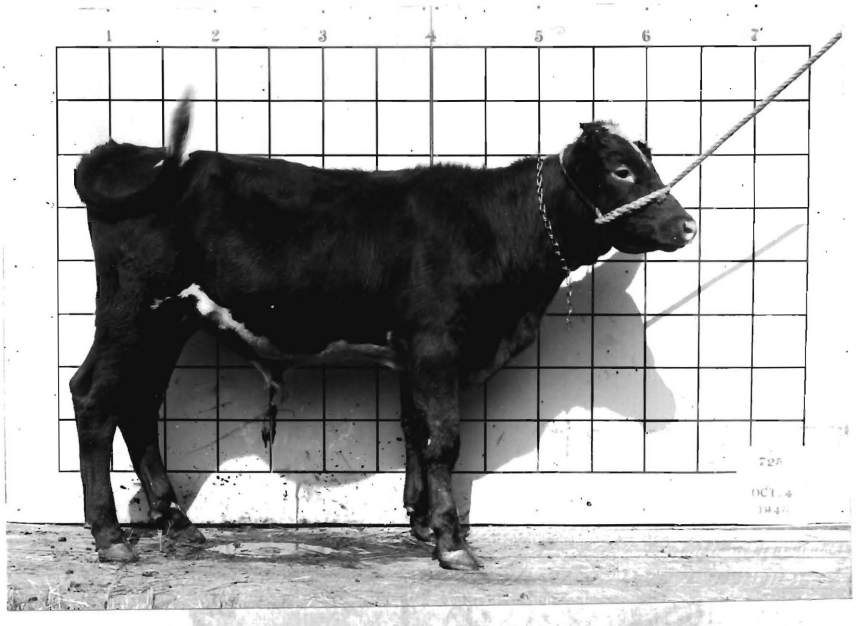


Figure 11. Calf 725 (Lot II) at start of experiment

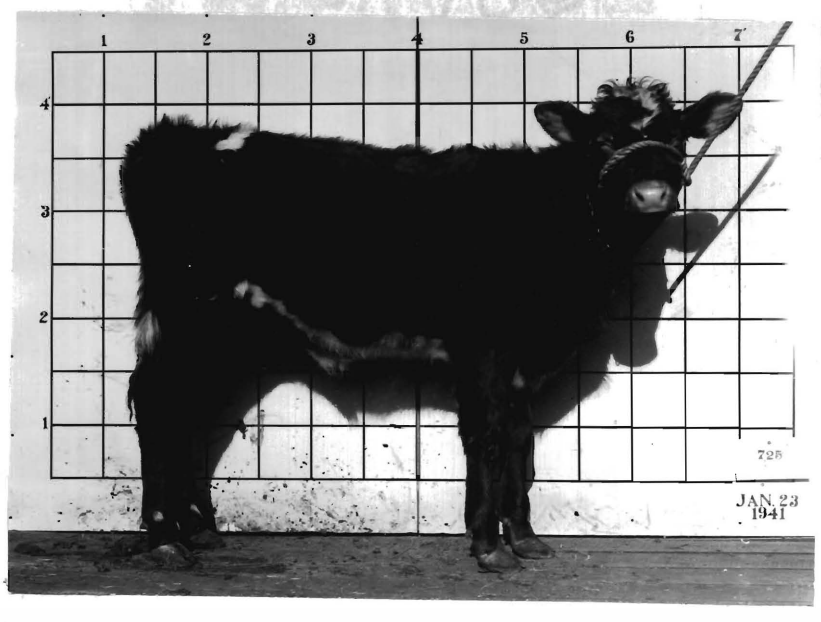


Figure 12. Calf 725 after 112 days feeding

Figure 13. Calf 725 (Lot II) at the end of the experiment

PART II

RESULTS AND DISCUSSIONS OF LOTS III AND IV

Rations 3 and 4 were designed to test the effects of 2.3 grams of phosphorus daily added to the basal rations (1 and 2). This addition made Ration 3 supply 9.3 grams of phosphorus daily and Ration 4, 11.5 grams. There was only one calf in each lot.

Weights and Body Measurements

Lot III (Calf 197) made decidedly greater gains in heart girth and weight, and slightly more gains in height, than did Lot IV (Calf 717). Calf 197 gained forty-three more pounds on the average-phosphorus hay plus a small phosphorus supplement than did Calf 717 on the high-phosphorus hay plus the same amount of phosphorus supplement. The gains in heart girth, height, and weight made by the two lots are shown in Table XI and figures 14, 15, 16, and 17. The addition of a phosphorus supplement to Ration 1 to form Ration 3 resulted in practically the same gain in pounds and no significant difference in height or heart girth. The same is true of Rations 2 and 4.

The calves in Lots III and IV were in about the same degree of flesh as Lot I, but were slightly superior to Lot II.

Feed Consumed

The amount of feed consumed was practically the same for both lots, there being only 0.11 of a pound daily difference for the entire nine periods. The amount of feed consumed by 28-day periods for 252 days, and the average

TABLE XI

GAIN IN HEART GIRTH, HEIGHT, AND WEIGHT OF LOTS III AND IV, BY TWENTY-EIGHT DAY PERIODS, 1940-41

28-day periods	Gain in heart girth (inches)		Gain in height (inches)		Gain in weight (pounds)	
	Lot III Calf 197	Lot IV Calf 717	Lot III Calf 197	Lot IV Calf 717	Lot III Calf 197	Lot IV Calf 717
1	1.59	0.00	0.67	0.59	30	21
2.	.91	0.00	0.17	0.66	29	23
3	.42	0.83	0.71	1.05	16	6
4	.42	0.75	1.13	-0.13	13	5
5	-.09	0.93	0.25	0.17	-12	18
6	1.50	0.75	0.00	0.58	32	21
7	0.42	0.32	1.32	1.08	14	0
8	1.42	1.08	0.17	0.42	23	29
9	1.00	0.75	1.13	0.50	25	4
Total	7.59	5.41	5.55	4.92	170	127
Average gain each period	.843	.60	.61	.546	18.88	14.11
Average daily gain	.03	.021	.021	.019	.67	.50

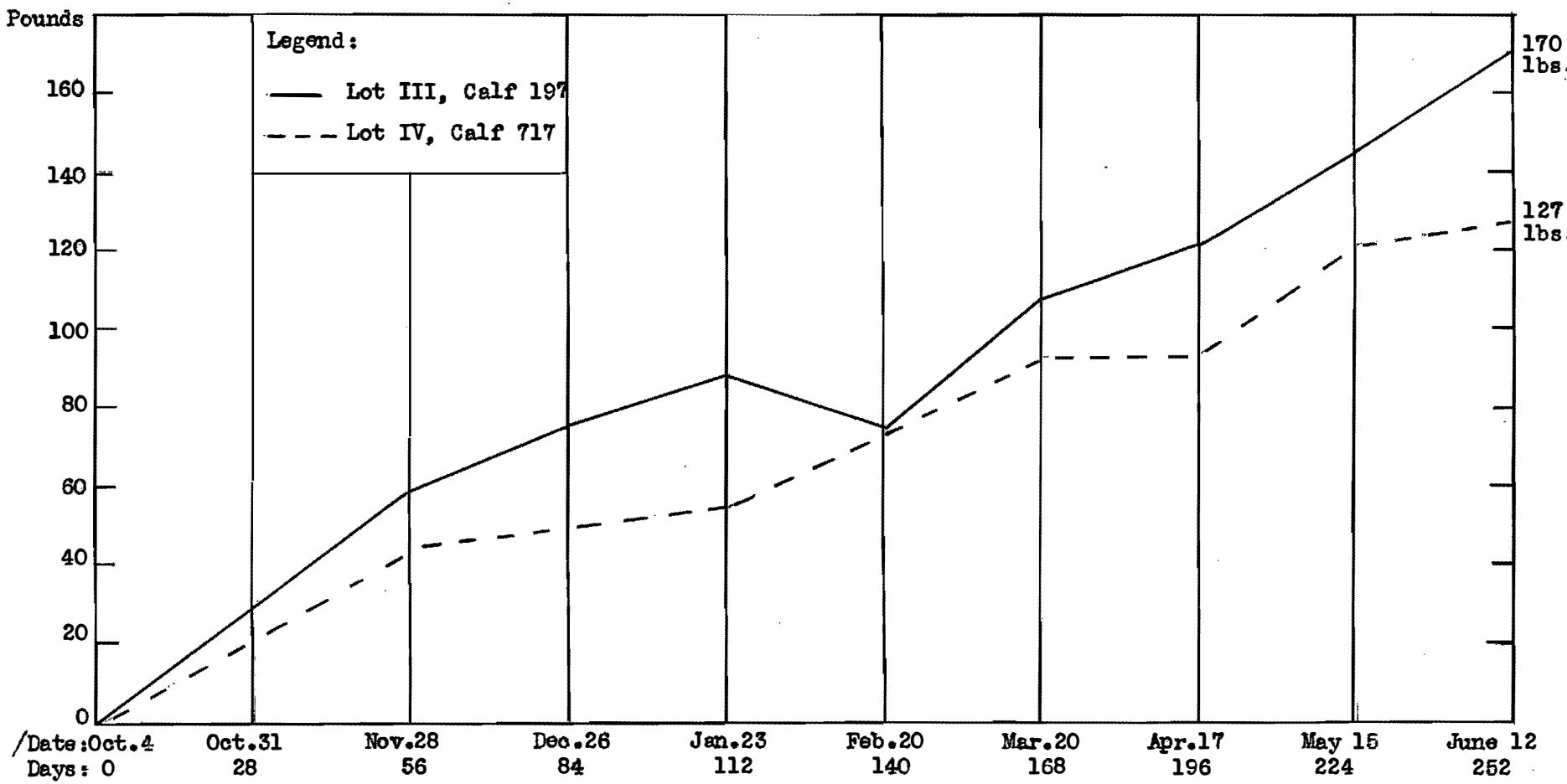


Figure 14. Gain in weight of Lots III and IV (1940-41), by 28-day periods

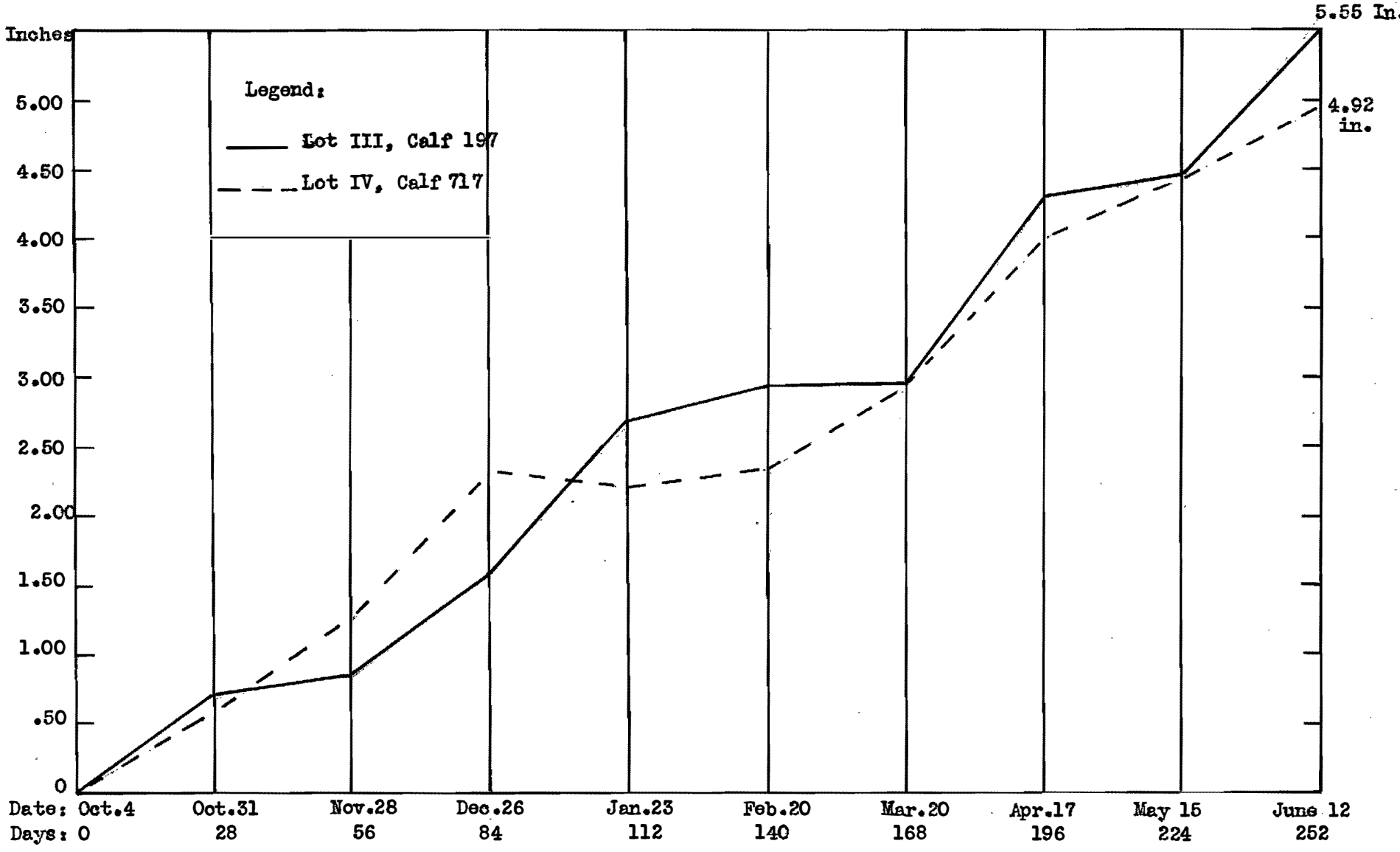


Figure 15. Gain in height of Lots III and IV, by 28-day periods

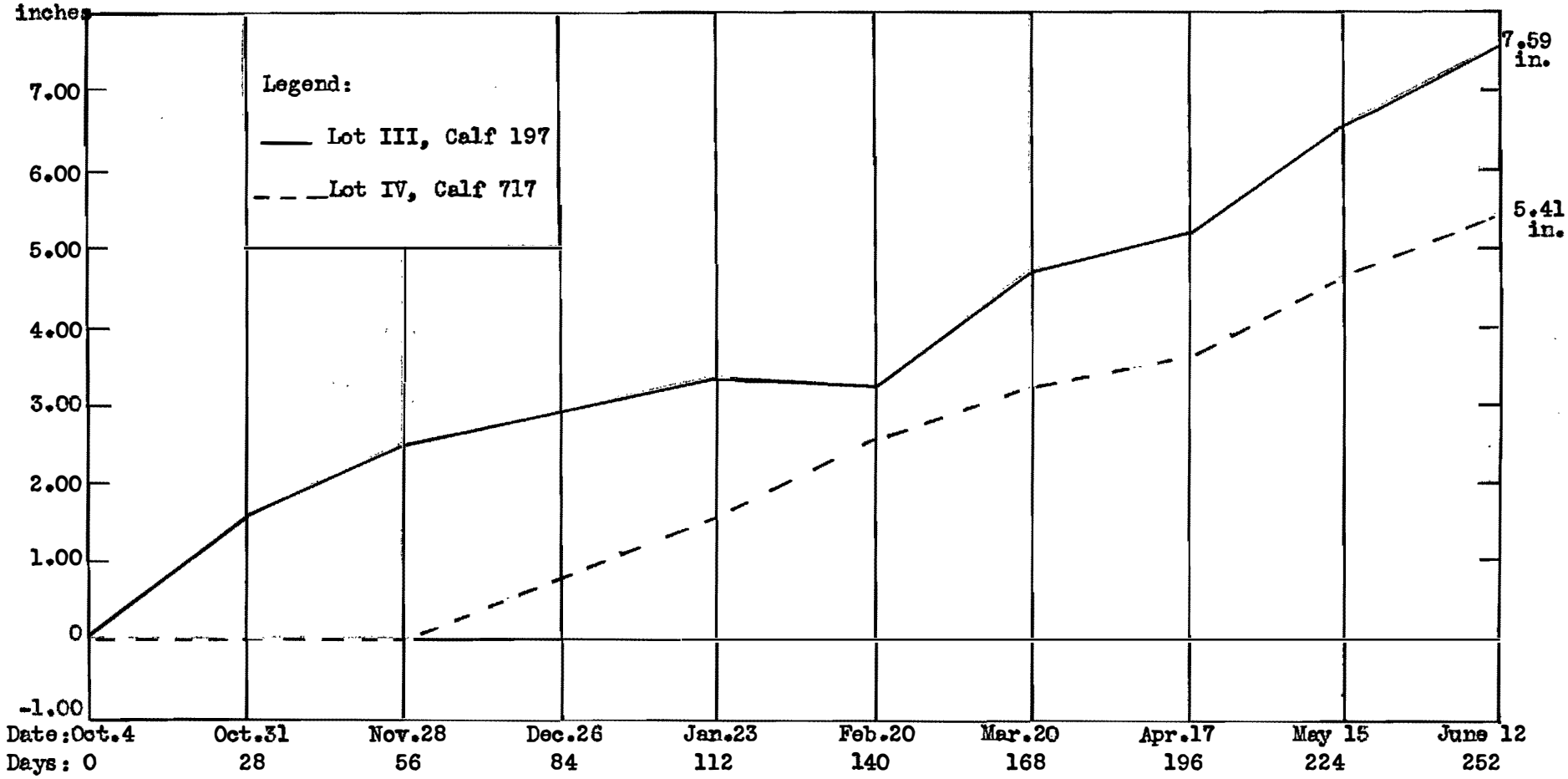


Figure 16. Gain in heart girth of Lots III and IV, by 28-day periods

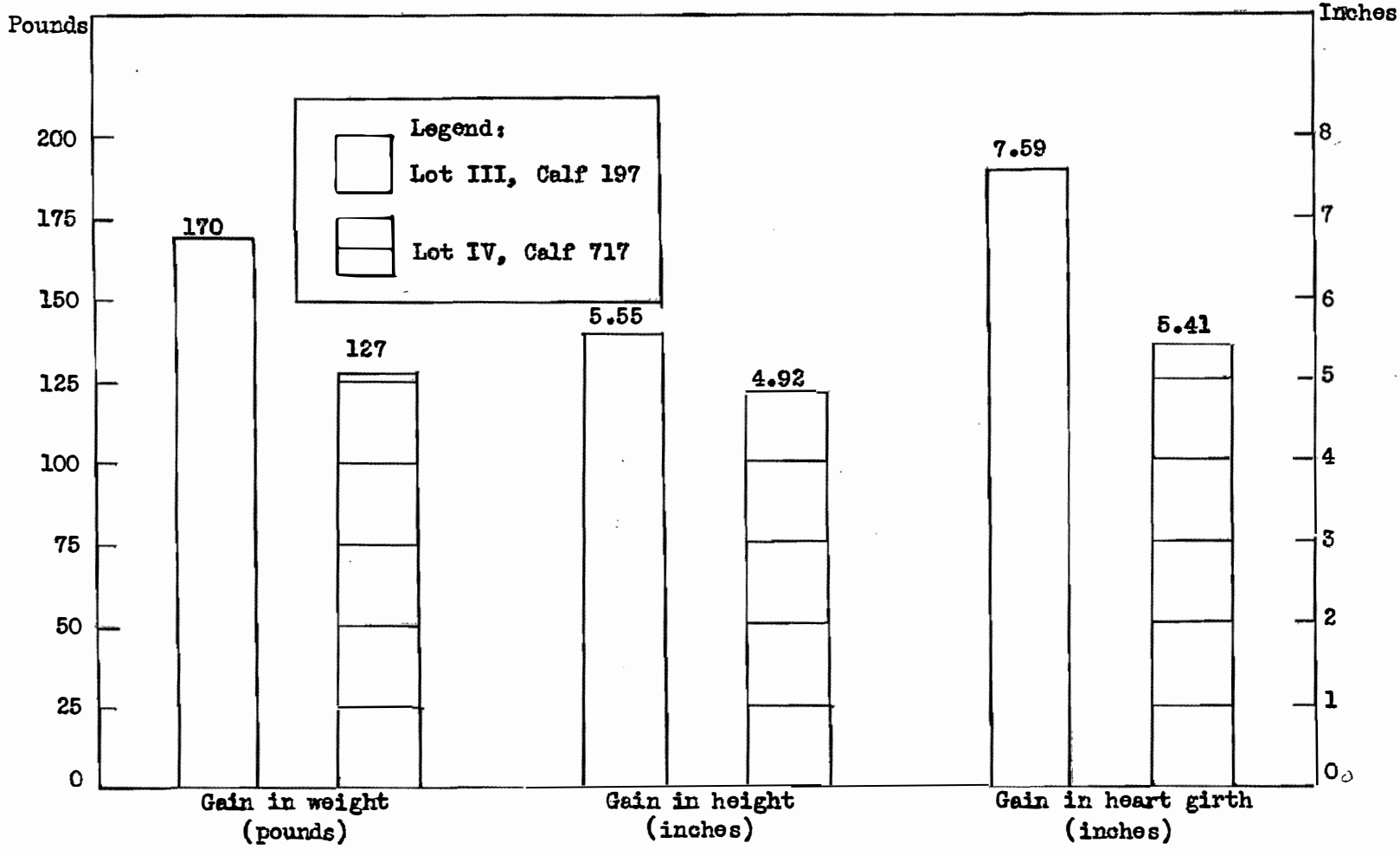


Figure 17. Gain in weight, height, and heart girth of Lots III and IV during the 252 days of the experiment

daily consumption during the preliminary period are shown in Table XII.

Blood Analyses

Both the feed phosphorus and blood phosphorus were higher in Calf 717 (Lot IV) than in Calf 197 (Lot III). The inorganic phosphorus of the blood average during the experiment for both calves barely met the normal minimum level, as suggested by Johnson(44), of a range of 5.4-7.4 mg. inorganic phosphorus in 100 cc. of whole blood. The blood phosphorus and feed phosphorus analyses are shown in Table XIII.

Blood calcium in Lot III (Calf 197) was considerably higher than in Lot IV (Calf 717). The blood calcium analyses are shown in Table XIV.

Pictures and Observations

The pictures on the following pages portray the calves at the beginning of the experiment, after 112 days of experimental feeding, and at the end of 252 days. Observe that the calves in both Lots III and IV were in good condition throughout the entire experiment.

Both lots maintained a normal appetite and had normal fecal droppings for the duration of the experiment. They would eat wood shavings and towards the latter part of the experiment, started eating dirt. Besides the above behavior, there was nothing unusual in their actions.

TABLE XII

FEED CONSUMED BY CALVES 197 AND 717 DURING PRELIMINARY AND 28-DAY PERIODS

Lot No.	Calf No.		Prelimi-nary--35 da.	1	2	3	4	5	6	7	8	9	Total last 9 periods
III	197	Total feed consumed	123.50	182.75	220.50	224.00	224.00	209.20	215.90	224.00	224.00	224.00	1948.35
		Av. daily consumption	3.53	6.52	7.87	8.00	8.00	7.47	7.71	8.00	8.00	8.00	7.73
IV	717	Total feed consumed	139.00	182.75	220.50	224.00	224.00	224.00	224.00	224.00	224.00	224.00	1971.25
		Av. daily consumption	4.96	6.52	7.87	8.00	8.00	8.00	8.00	8.00	8.00	8.00	7.82

TABLE XIII

INORGANIC PHOSPHORUS OF THE BLOOD IN MG. PER 100CC. OF WHOLE BLOOD AND THE AVERAGE DAILY FEED PHOSPHORUS(GRAMS)

Lot No.	Calf No.	Amount of	Days										Average during experiment
			Beg.	28	56	84	112	140	168	196	224	252	
III	197	Food (grams)	3.3	7.6	9.0	9.3	8.2	8.7	9.0	9.3	9.3	9.3	8.85
		Blood (mg.)	4.29	6.43	6.21	5.73	5.75	4.99	5.32	5.24	5.08	5.45	5.57
IV	717	Food (grams)	3.7	9.4	11.1	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.2
		Blood (mg.)	4.88	6.43	6.49	6.20	5.61	5.48	6.54	5.59	5.41	5.85	5.95

TABLE XIV

BLOOD CALCIUM IN MG. PER 100 CC. OF BLOOD PLASMA

Lot No.	Calf No.	Periods during experiment				Average during experiment
		Preliminary	Beginning	112 days	196 days	
III Average phosphorus plus supplement	197	9.07	10.93	10.66	10.45	10.68
IV High phosphorus plus supplement	717	8.75	9.77	9.30	7.78	8.95

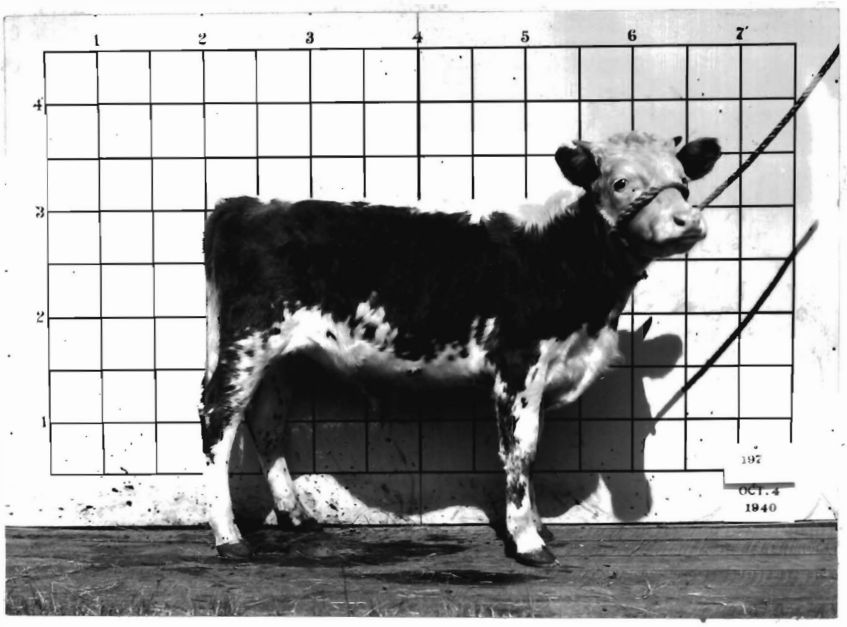


Figure 18. Calf 197 (Lot III) at the beginning of the experiment

Figure 19. Calf 197 (III, Lot) after 112 days feeding

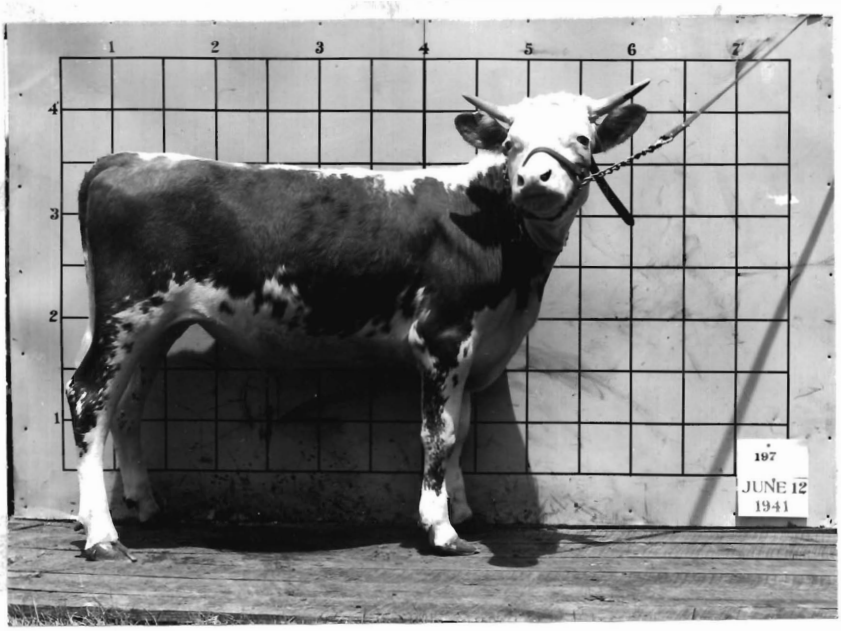


Figure 20. Calf 197 (Lot III) at the end of the experiment

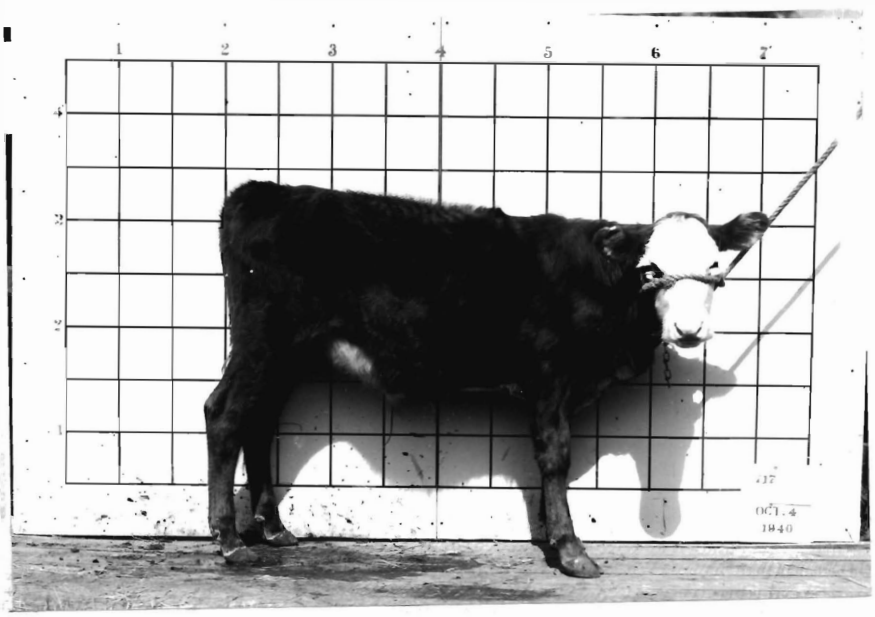


Figure 21. Calf 717 (Lot IV) at the start of the experiment

Figure 22. Calf 717 (Lot IV) after 112 days feeding

Figure 23. Calf 717 (Lot IV) at the end of the experiment

PART III

RESULTS AND DISCUSSIONS OF LOTS IX AND X

Rations 9 and 10 were designed to study the effects of the addition of phosphorus to Rations 7 and 8. Ration 7 was designed low in phosphorus and differed from the basal rations in that cornstarch, beet pulp, and casein were mixed with the hay in place of the cornmeal, as in Rations 1 and 2. Ration 8 differed from Ration 7 only in the kind of hay used, the former using .24-percent-phosphorus red clover hay and the latter using the .16-percent-phosphorus red clover hay. Ration 7 supplied 5 grams of phosphorus daily, while Ration 8 supplied 7 grams.

One calf was on Ration 9 during the experiment and the calf that was started on Ration 10 was removed (for reasons given later) after 140 days and the calf that was in Lot VIII was placed in Lot X for the last 112 days.

Weights and Body Measurements

Calf 199 (Lot IX) made decidedly greater gains than did Calf 716 (Lot X), and some greater gains than did Calf 724, which was substituted for Calf 716 on the 140th day of the experiment. The previous behavior and discussion of Calf 724 for the first 140 days is reported in Part VII. Calf 716 was removed on the 140th day because he made poor gains, seemed unthrifty, and was considered unsuitable for the experiment. The results for Calf 716, after its removal from Lot X, are reported in Part VIII.

Calf 199 in Lot IX gained 181 poun s for the 252 days, or an average of .72 of a pound a day. This was the greatest gain of any lot in the experiment, but only slightly exceeding Lots I and III. However, for the first 140 days, Calf 199 gained 113 pounds while Calves 200 and 723, in Lot I, gained 101 and 64 pounds respectively for the same period. After the substitution in Lot X, the gains in weight for the next 112 days for Lots IX and X were 68 and 54 pounds respectively. The calf in Lot IX, therefore, made 24 percent more gain than Calf 724 in Lot X.

Feed Consumed

Calf 199 ha a fairly uniform feed consumption, averaging 7.82 pounds a day. For the last seven periods, Calf 199 (Lot IX) failed only once to average eight pounds of feed consumed a day. For the five periods, Calf 716 (Lot X) was studied in this part, he consumed on the average of 6.69 pounds of feed a day. For only one period during that time did he average 8 pounds of feed consumed a day. On the other hand, Calf 724, substituted for him, averaged 7.96 pounds. For the last four periods, there was little difference in the amount of feed consumed by Lots IX (Calf 199)and X (Calf 724). The feed consumptions are shown in Table XVI.

Blood Analyses

Calf 199 maintained a fairly uniform blood phosphorus level and averaged 5.59 mg. which is close to the minimum normal, a suggested by Johnson(44). For the first 140 days, Calf 716 maintained a slightly higher phosphorus level than did Calf 199 for the same period. Calf 724 had a higher feed phosphorus intakethan did Calf 199, but a slightly lower

TABLE XV

GAIN IN HEART GIRTH, HEIGHT, AND WEIGHT OF LOTS IX and X, BY 28-DAY PERIODS

Period (28 days)	Gain in heart girth (inches)			Gain in height (inches)			Gain in weight (pounds)		
	Lot IX Calf 199	Lot X Calf 716	Lot X Calf 724	Lot IX Calf 199	Lot X Calf 716	Lot X Calf 724	Lot IX Calf 199	Lot X Calf 716	Lot X Calf 724
1	1.41	0.42		0.50	-0.09		33	17	
2	0.84	0.50		0.25	0.34		30	13	
3	1.08	0.88		0.71	0.46		19	2	
4	0.08	-0.63		0.95	0.70		8	-13	
5	1.09	-0.25		-0.08	0.09		23	9	
6	1.25		0.17	0.33		0.50	31		16
7	0.75		0.67	1.42		1.33	11		7
8	0.91		0.58	0.42		0.75	19		13
9	0.59		1.08	0.41		0.08	7		18
Total	8.00	0.92	2.50	4.91	1.50	2.66	181	28	54
Gain last 112 da.	3.50		2.50	2.58		2.66	68		54
Av. gain each period	.88	0.18[a]	.625[b]	0.54	0.30[a]	0.665[b]	20.1	5.6[a]	13.5[b]
Av. daily gain	.031	.006	.022	.019	.01	.024	.72	.20	.48

a Average for five periods.
b Average for four periods.

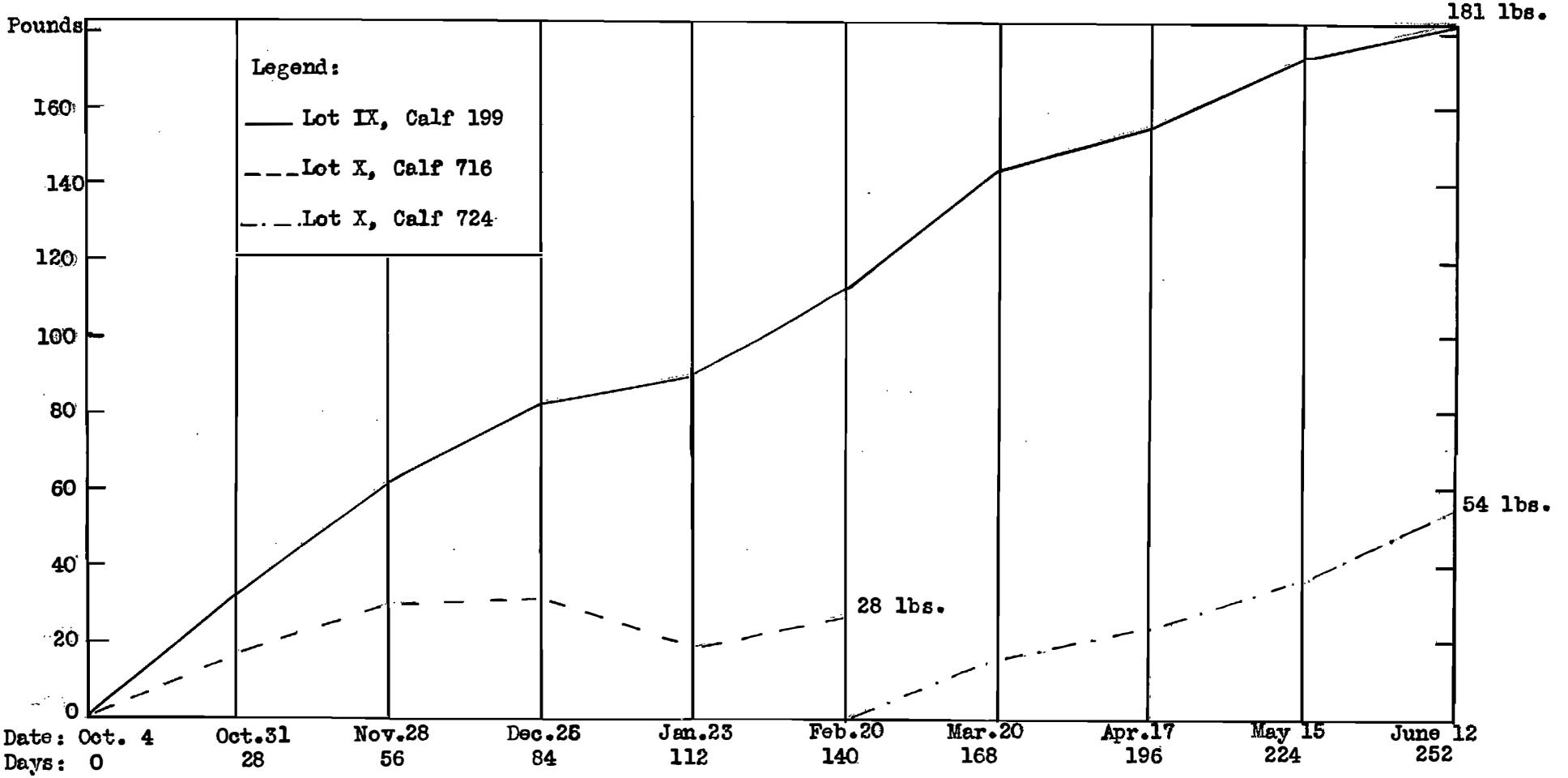


Figure 24. Gain in weight of Lots IX, Calf 199; and Calf 716, Lot X, for 140 days and then 724 (Lot X) for the last 112 days

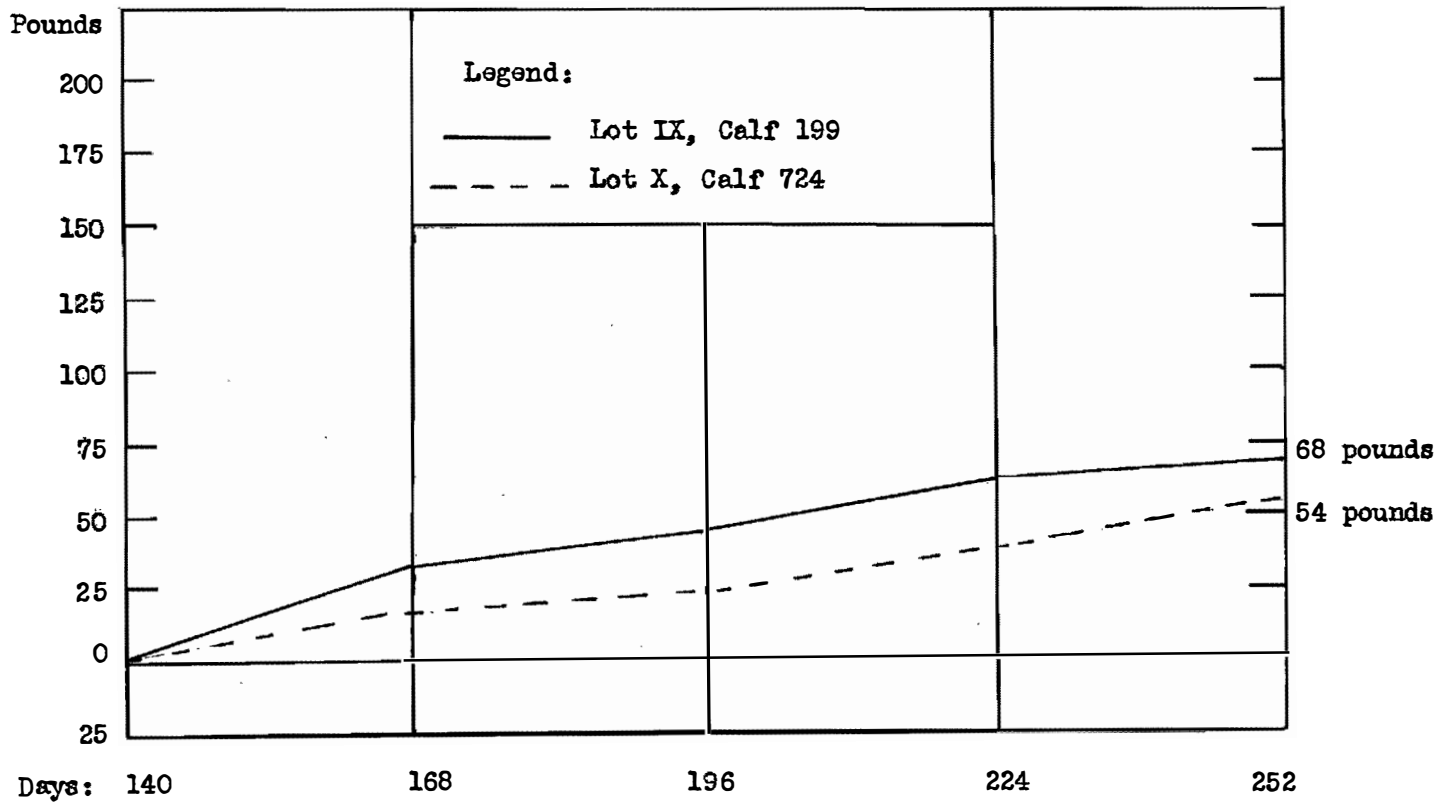


Figure 25. Gain in weight for Lots IX and X (Calf 724) the last 112 days of the experiment.

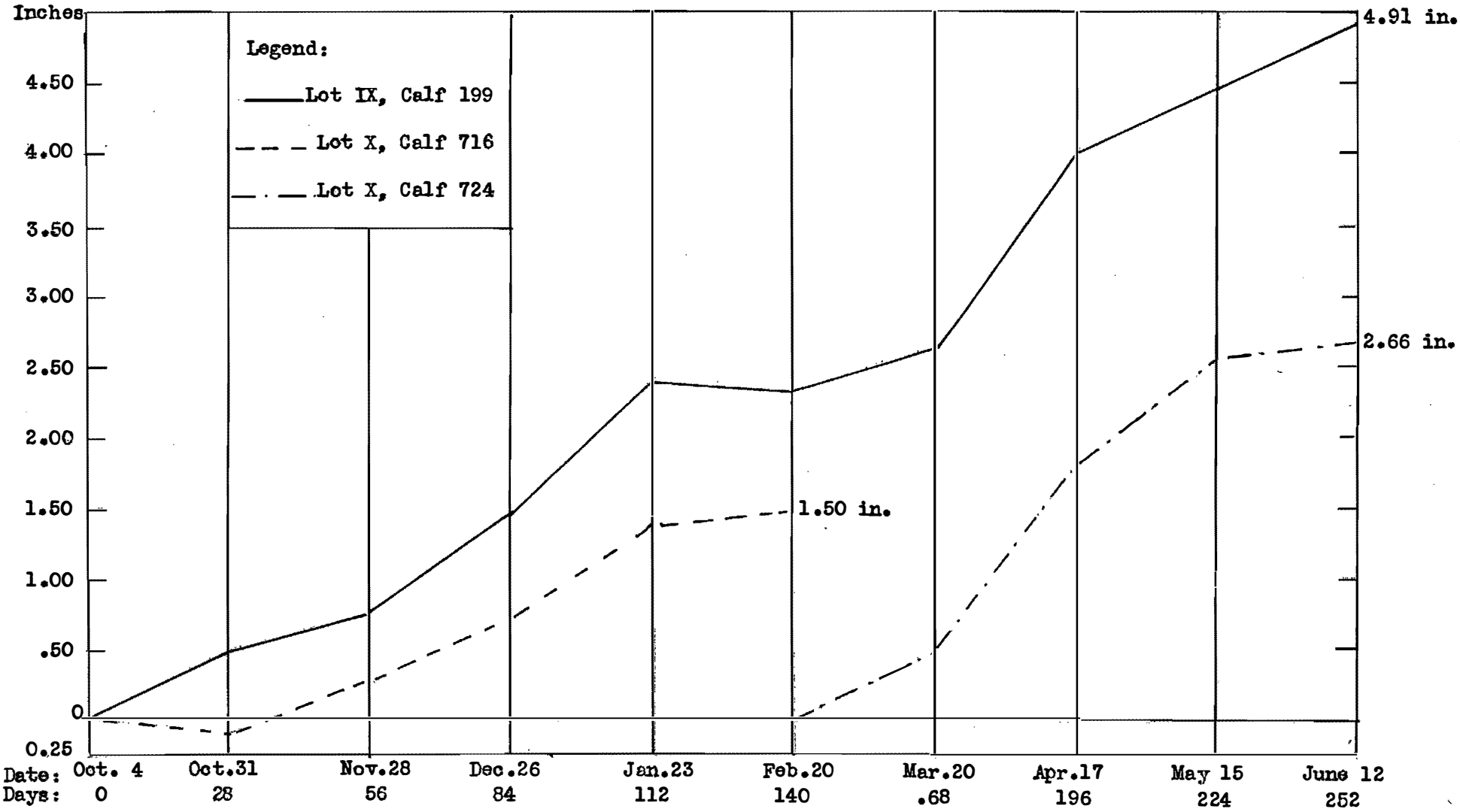


Figure 26. Gain in height by 28-day periods of Lot IX, Calf 199; and Lot X, Calf 716 for 140 days and then Calf 724 for last 112 days

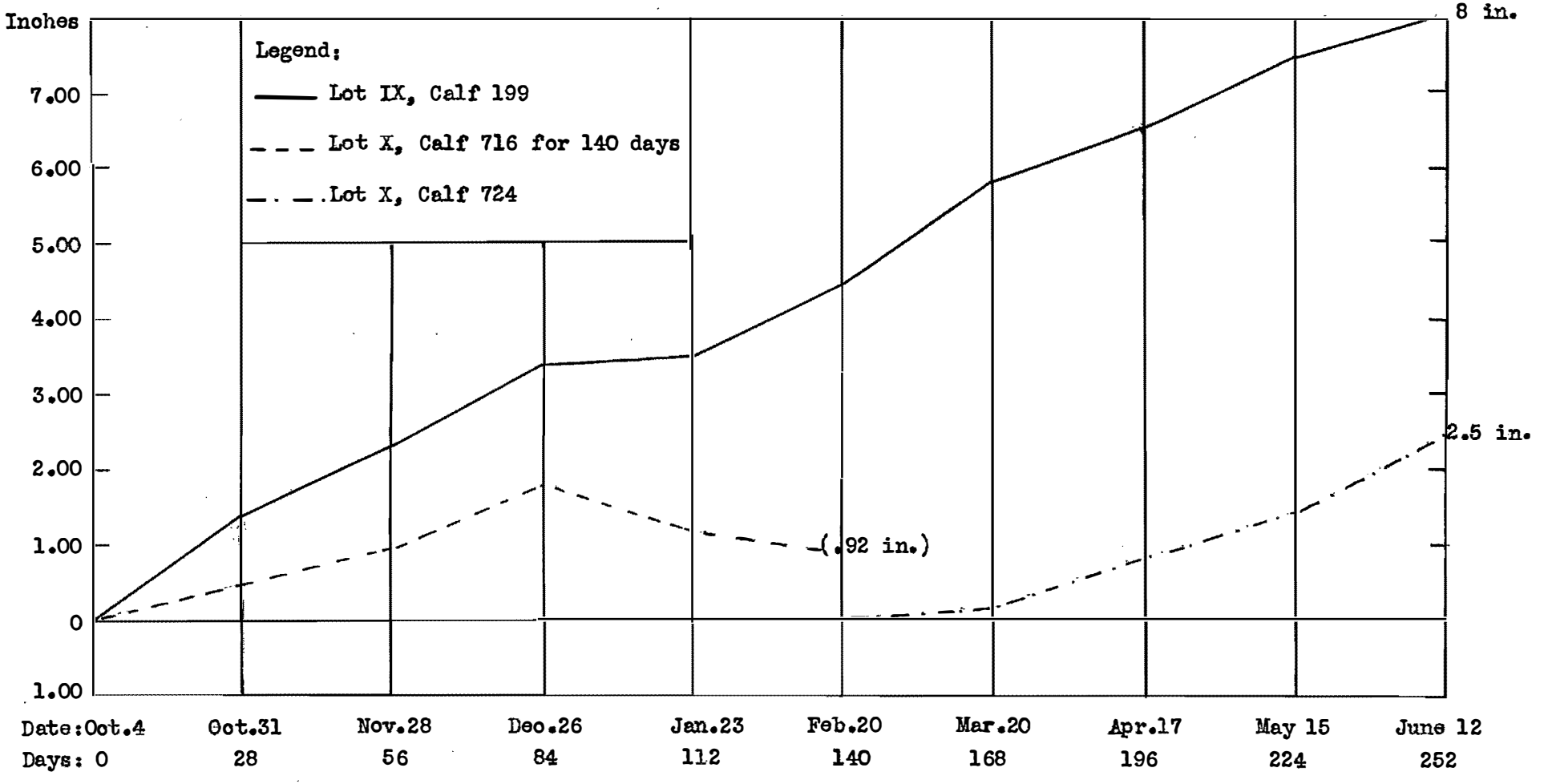


Figure 27. Gain in heart girth, by 28-day periods, of Lots IX and X.

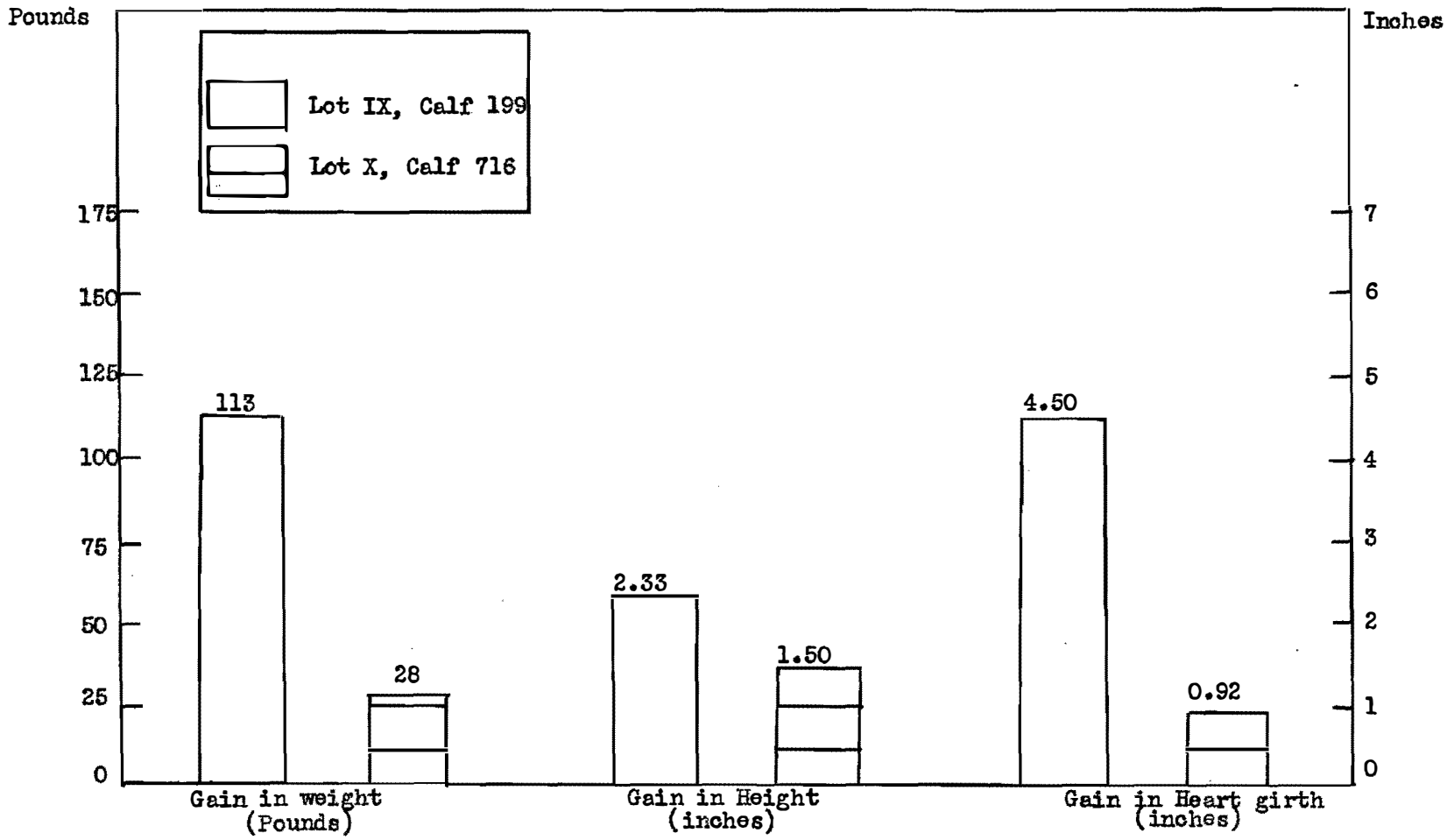


Figure 28. Total gain in weight, height, and heart girth for the first five periods (140 days) for Lots IX and X

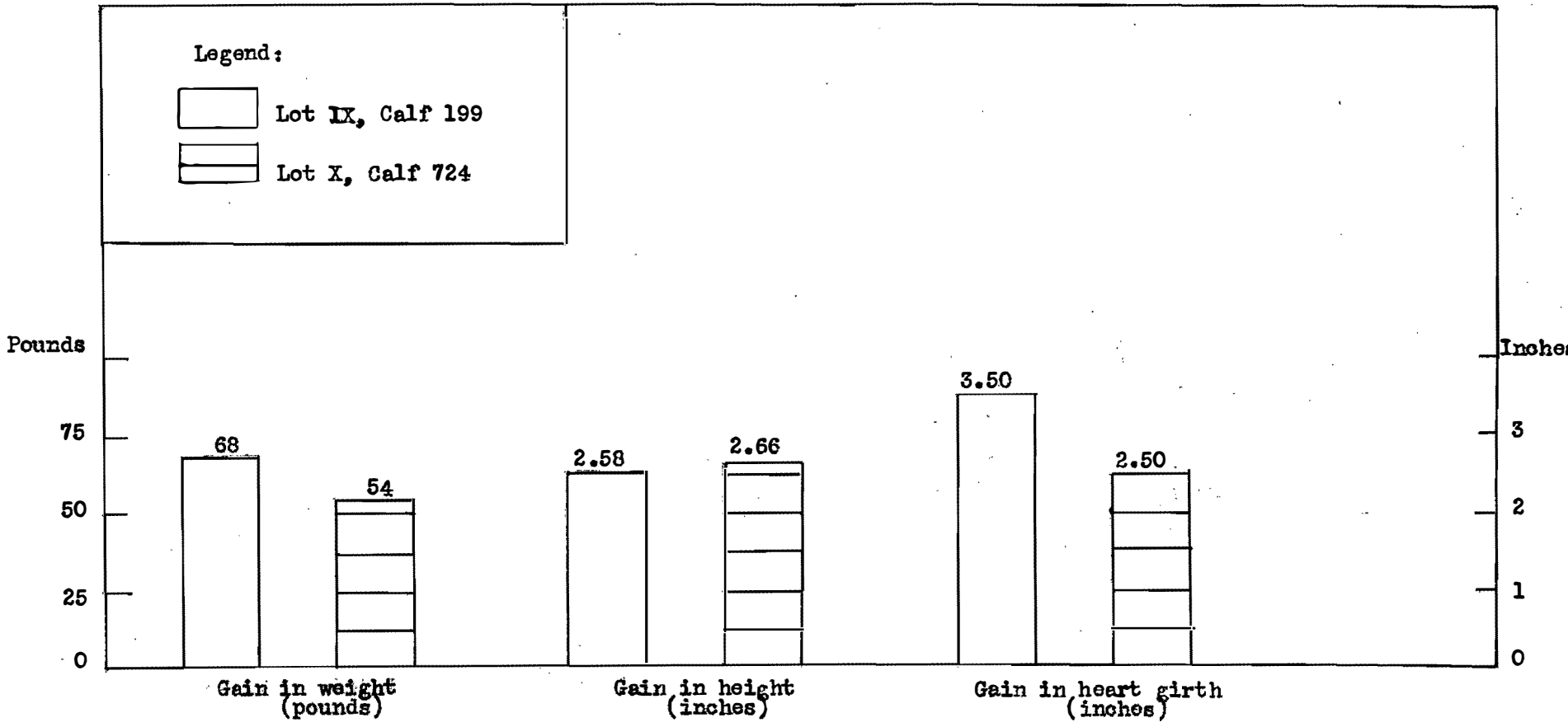


Figure 29. Gain in weight, height, and heart girth of Lots IX and X for the last four periods (112 days)

TABLE XVI

FEED CONSUMED DURING PRELIMINARY AND TWENTY-EIGHT DAY PERIODS, BY LOT IX AND CALVES 716 AND 724 WHILE THEY WERE IN LOT X

Lot No.	Calf No.		Prelimi-nary 35 da.	1	2	3	4	5	6	7	8	9	Total last 9 periods
IX	199	Total feed consumed	129.75	182.75	220.50	224.00	223.50	224.00	224.00	224.00	224.00	224.00	1970.75
		Av. daily consumpt.	3.70	6.52	7.87	8.00	7.98	8.00	8.00	8.00	8.00	8.00	7.82
X	716	Total feed consumed	142.75	182.75	219.75	224.00	185.79	124.75					937.04
		Av. daily consumpt.	4.07	6.52	7.8	8.00	6.63	4.45					6.69
X	724	Total feed consumed							224.00	221.05	223.50	224.00	892.55
		Av. daily consumpt.							8.00	7.89	7.98	8.00	7.96

blood phosphorus average. The blood phosphorus and feed phosphorus averages are shown in Table XVII.

The blood calcium level was normal and practically equal for calves 199 and 724, while that of Calf 716 was lower than the other two calves. These levels are shown in Table XVIII.

Pictures and Observations

The pictures were taken at the usual times. Calf 199 (Lot IX) seemed to have made considerable growth and this is easily seen when a comparison of the pictures is made. Judging from the pictures, Calf 716 does not seem to be in a very thrifty condition and does not seem to have made much growth. Note the listless appearance on the picture made in January, of Calf 716. The January picture of Calf 724 shows him as he appeared 28 days before being put in Lot X. The only difference in Rations 8 and 10 was the addition of a phosphorus supplement to 10. The next picture shows that he was still in a good growing condition and evidently still had plenty of life about him. These pictures are shown in Figures 30, 31, 32, 33, 34, 35, and 36.

Calf 199 (Lot IX) maintained normal fecal droppings, appetite, and behavior for the duration of the experiment. His general appearance was always good and he usually seemed to have plenty of pep about him. There was nothing unusual noted in his behavior or actions. From the very first, he ate shavings, and towards the latter part of the experiment (last 84 days) he would eat and lick the dirt at the edge of his stall.

Calf 716 (Lot X) started the experiment apparently feeling good. His general appearance, appetite, and fecal droppings were normal. However,

TABLE XVII

INORGANIC PHOSPHORUS OF THE BLOOD IN MG. PER 100 CC. OF WHOLE BLOOD AND THE AVERAGE DAILY FEED PHOSPHORUS (GRAMS)

Lot No.	Calf No.	Amount of	Days									Average during experiment
			Beg.	28	56	84	112	140	168	196	224	252	
IX Av. P. plus casein plus phos. sup.	199	Food (gms.)	3.5	6.0	7.1	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.13
		Blood (mg.)	4.43	5.94	5.75	5.78	5.82	5.09	5.55	5.40	5.80	5.25	5.59
X High phosphorus plus casein plus phos. sup.	716	Food (grams)	3.8	7.6	9.0	9.3	7.7	5.2					7.7
		Blood (mg.)	3.98	6.10	5.72	5.80	5.30	5.19					5.62
X High phos. plus casein plus phos. sup.	724	Food (grams)							9.3	9.2	9.3	9.3	9.27
		Blood (mg.)							5.69	5.59	5.27	5.51	5.41

TABLE XVIII

BLOOD CALCIUM IN MG. PER 100 CC. OF BLOOD PLASMA

Lot No.	Calf No.	Periods during experiment				Average during experiment
		Preliminary	Beginning	112 days	196 days	
IX	199	7.88	8.92	10.42	9.84	9.72
X	716	8.42	9.38	8.53		8.95
X	724				9.77	9.77

besides eating wood shavings, he soon started to gnawing on his trough and on the wooden parts of his stall. Also, he liked the dirt that was within reaoh. His appetite remained good for awhile, but soon reaohed the point where it was very poor. He did not like his feed and started refusing it in larger quantities eaoh day. The feed consumption ohart (Table XVII) shows that he was consuming only 4.45 pounds of feed a day, when at the same time Lot IX, Calf 199, was consuming 8 pounds of feed a day. Before he was removed from Lot X, Calf 716 showed a pronounoed oraving for dirt and clay.

The oalf substituted in Lot X, Calf 724, was in a healthy oondition when placed in Lot X, and retained this thrifty growing oondition as long as the experiment continued. This oalf would also nibble at the shavings as if seeking to satisfy its appetite.

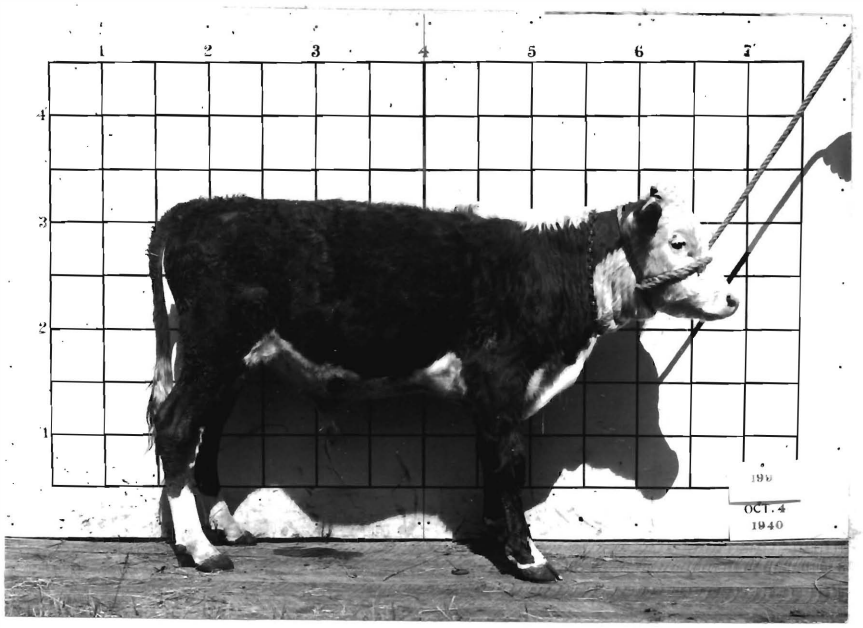


Figure 30. Calf 199 (Lot IX) at the start of the experiment

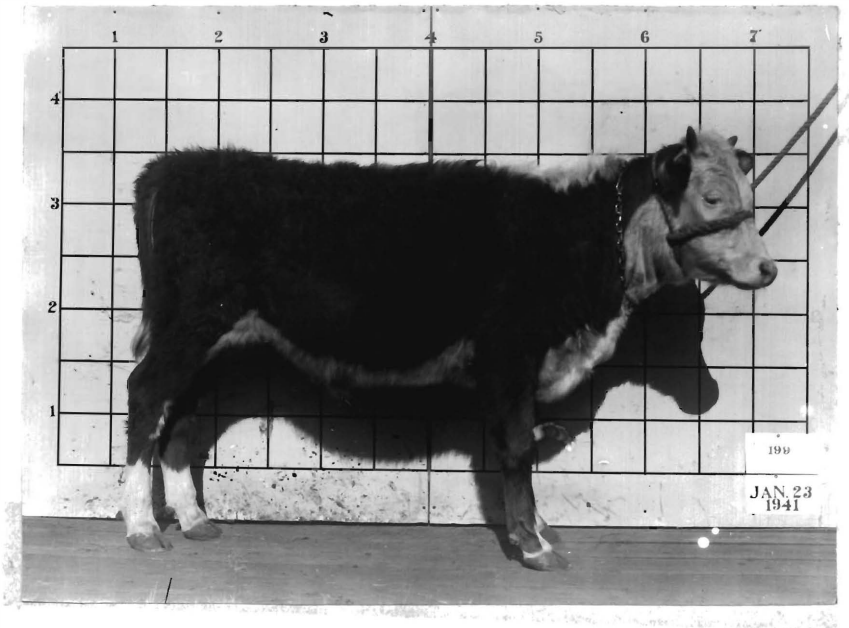


Figure 31. Calf 199 (Lot IX) after 112 days feeding

Figure 32. Calf 199 (Lot IX) at the end of the experiment

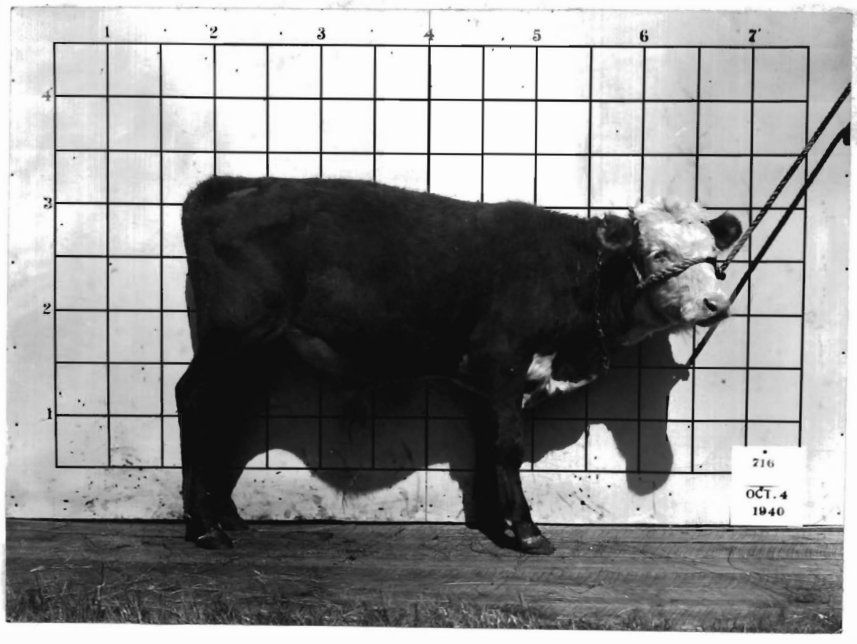


Figure 33. Calf 716 (Lot X) at the start of the experiment

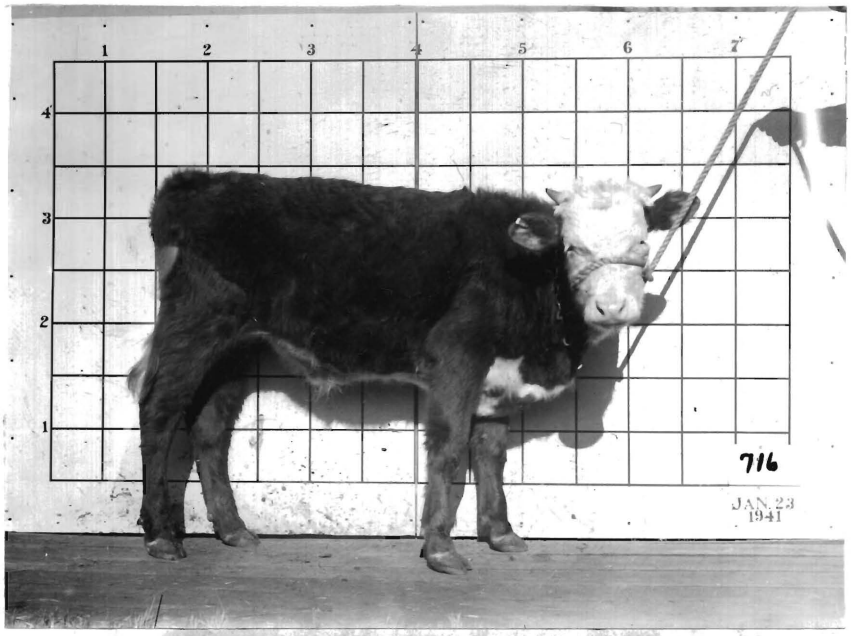


Figure 34. Calf 716 (Lot X) after 112 days feeding

Figure 35. Calf 724 (Substitute in Lot X) 28 days before being put in Lot X

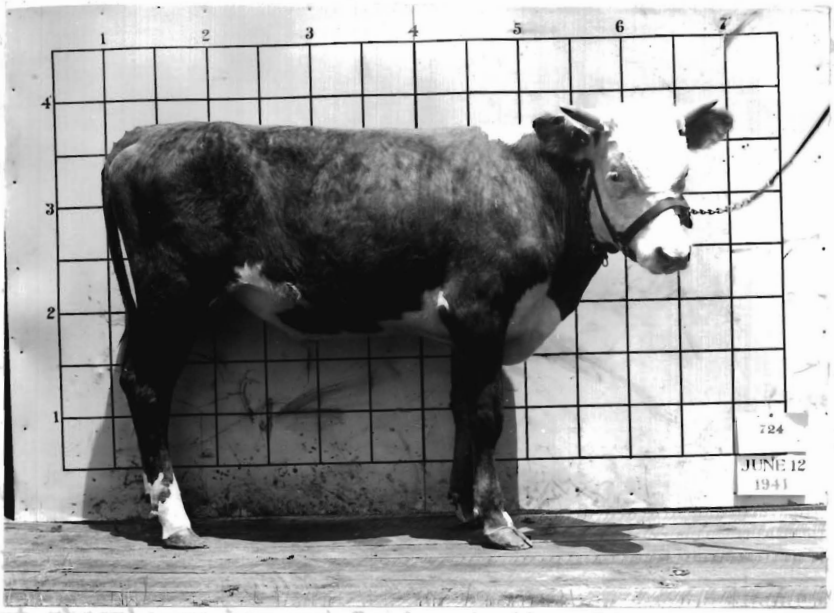


Figure 36. Calf 724 at the end of the experiment, or at the end of the 112 days in Lot X

PART IV

RESULTS AND DISCUSSIONS OF LOTS V (Calf 722) AND VI (Calf 718)

The previous year's work showed some indications that the efficiency of the protein in clover hays might vary as well as the phosphorus content. It was thought that there might be a difference in biological value of the protein in red clover hay, and in casein, for growing calves up to the time that their ruminant stomach is developed sufficiently for the bacteria to make available the simpler nitrogen compounds to the calf. Rations 5 and 6 were planned for a study of these possibilities. Six tenths of a pound of cottonseed meal was incorporated into each of these rations as an additional source of protein. The only variable was the difference in composition of the two red clover hays. Both rations had 66 percent hay in them, Ration 5 using the .16-percent phosphorus hay and Ration 6, the .24-percent phosphorus hay. Cornstarch, beet pulp, cottonseed meal, salt, and cod liver oil were the other feeds used in these two rations.

Weights and Body Measurements

For the first five periods there was practically no difference in the gains of Lot V (Calf 722) and Lot VI (Calf 718). At the end of the 140-day feeding, they weighed only slightly more, 7 and 8 pounds respectively, than they did at the beginning of the experiment. Both calves were placed on Ration 5 plus 10 grams of phosphorus daily for the last 112 days.

For these last four periods, the gains in weight were 85 and 76 pounds respectively. The increase in heart girth was noticeably improved. The increase in height for the last four periods was nearly one inch greater than the increase in height for the first five periods for both calves. These gains are shown in Table XIX.

Feed Consumed

The feed consumption of the calves in both Lots V and VI fluctuated but never reached the maximum level of eight pounds a day until the phosphorus supplement was added. The average daily feed consumption for the 252 days of the experiment was only a little in excess of seven pounds a day. The feed consumption is shown in Table XX.

Blood Analyses

The inorganic phosphorus of the blood of Calves 722 and 718 was normal the first 56 days of the experiment, and then remained below normal or close to the normal minimum level(44) until the last 112 days at which time the inorganic phosphorus of the blood increased.

The first week after the rations were changed, the inorganic phosphorus of the blood was raised from 4.75 mgm. and 4.42 mgm. to 5.72 and 7.00 mgm. for Calves 722 and 718. For the second week after the change, the inorganic phosphorus of the blood was 6.88 and 6.83 mgm. respectively and for the third week, 7.16 and 5.97 mgm. respectively.

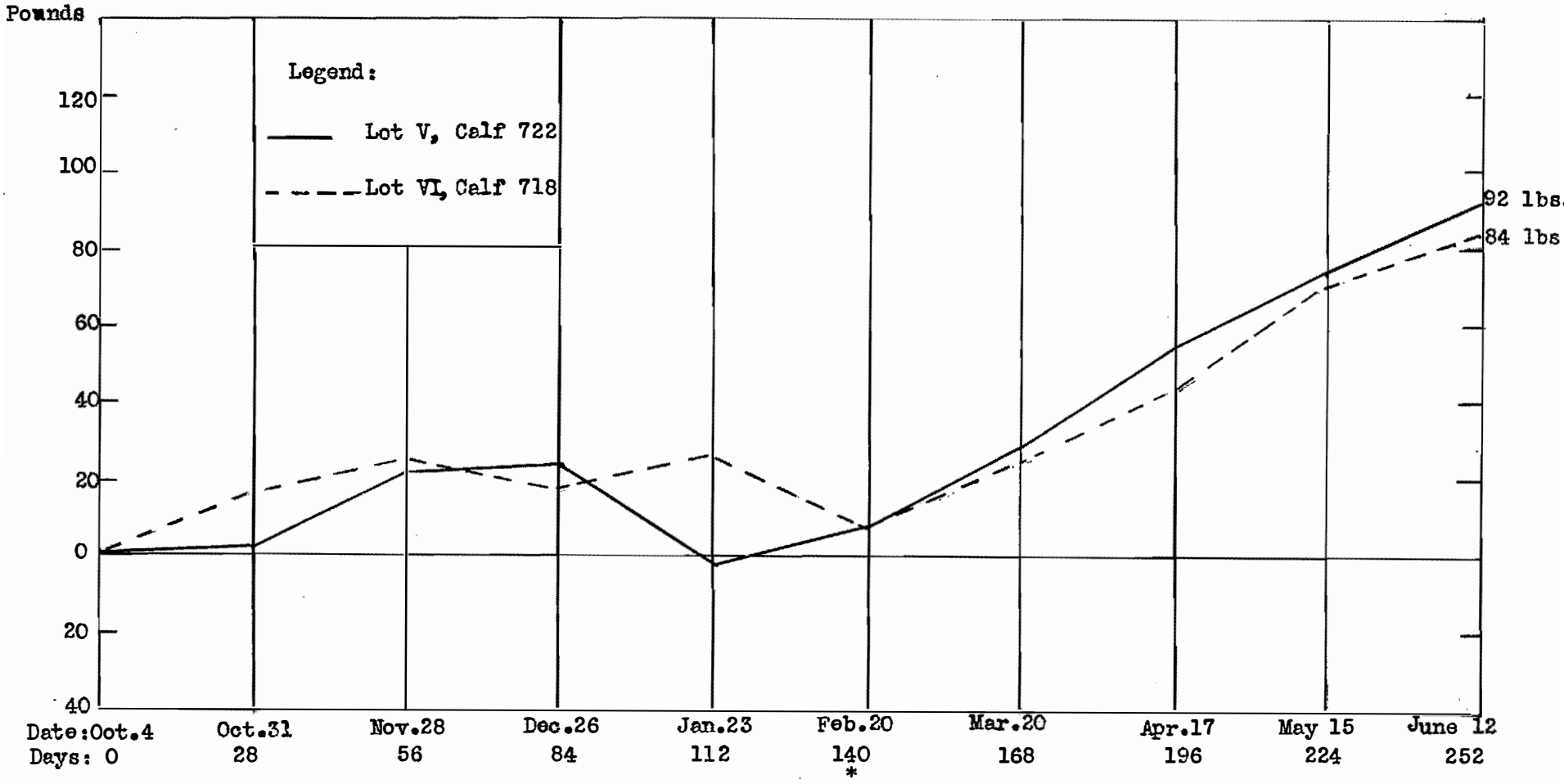
The average feed phosphorus consumed during the experiment was 1.26 grams higher with Calf 718, whereas the blood phosphorus average during the experiment was .56 mgm. higher with Calf 722.

TABLE XIX

GAIN IN HEART GIRTH, HEIGHT, AND WEIGHT FOR CALVES 718 and 722 (LOTS V AND VI), BY 28-DAY PERIODS, BEFORE AND AFTER PHOSPHORUS WAS ADDED TO THE RATIONS

Period (28 days)	Gain in heart girth (inches)		Gain in height (inches)		Gain in weight (pounds)	
	Lot V Calf 722	Lot VI Calf 718	Lot V Calf 722	Lot VI Calf 718	Lot V Calf 722	Lot VI Calf 718
1	0.33	0.91	0.25	0.33	1	17
2	0.25	0.34	0.50	0.75	21	8
3	0.25	-0.67	-0.20	-0.20	2	-7
4	-0.92	0.25	0.70	0.54	-25	9
5	0.42	-0.17	0.25	0.00	8	-19
Total 1st 5 periods	0.33	0.66	1.50	1.42	7	8
6[a]	0.50	0.42	0.25	0.33	22	18
7	0.58	1.00	0.84	0.58	26	18
8	0.92	1.17	0.16	0.75	20	28
9	1.42	0.58	1.09	0.67	17	12
Total last 4 periods	3.42	3.17	2.34	2.33	85	76
Total all per.	3.75	3.83	3.84	3.75	92	84
Av. gain each per.	.416	.425	.426	.416	10.2	9.33
Av. daily gain	.014	.015	.015	.014	0.36	0.33

A -Both calves placed on Ration 5 plus 10 grams of phosphorus daily for the rest of the experiment.



*Both calves put on Lot V ration plus 10 gm. P. daily.

Figure 37. Gain in weight of Lots V and VI, by 28-day periods

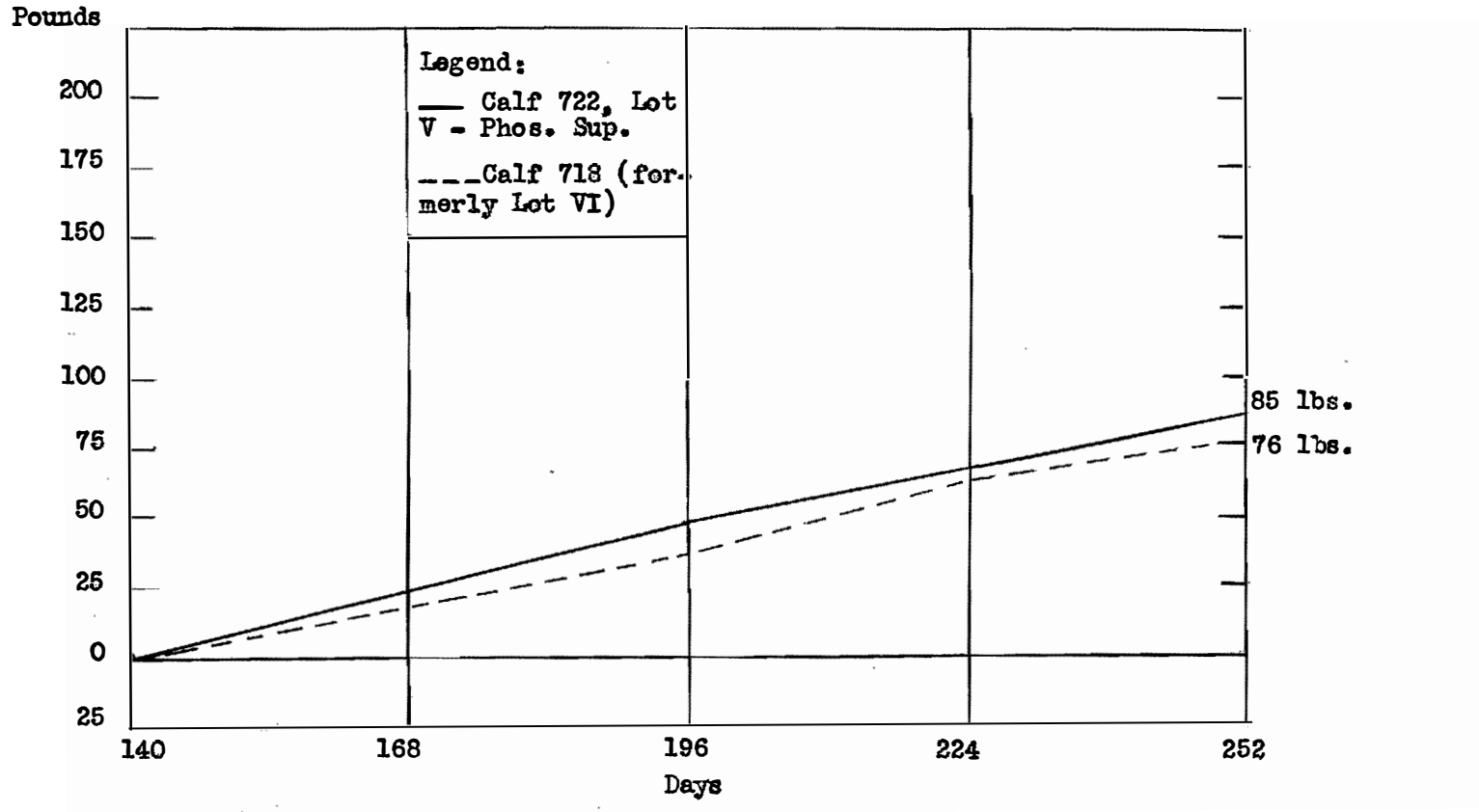
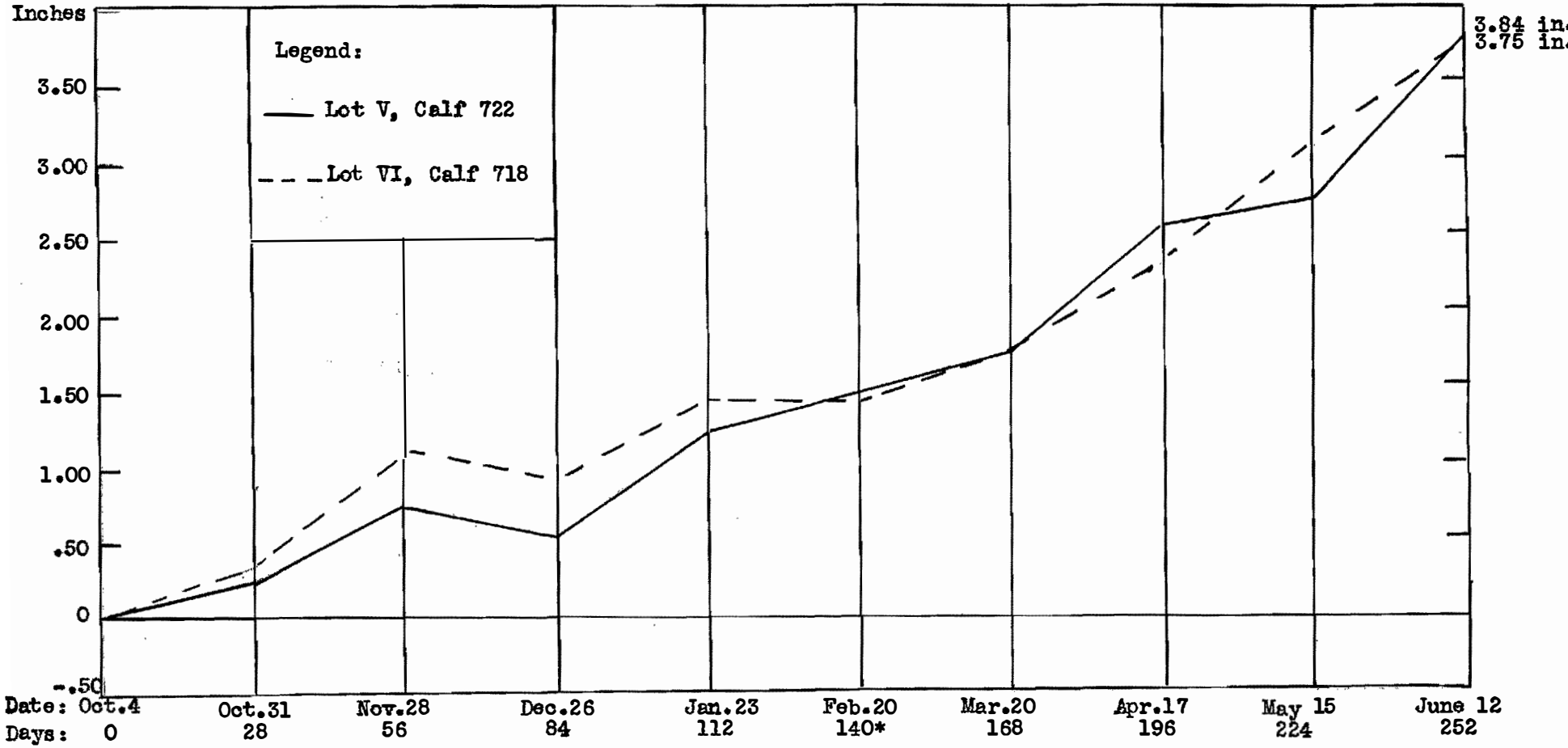
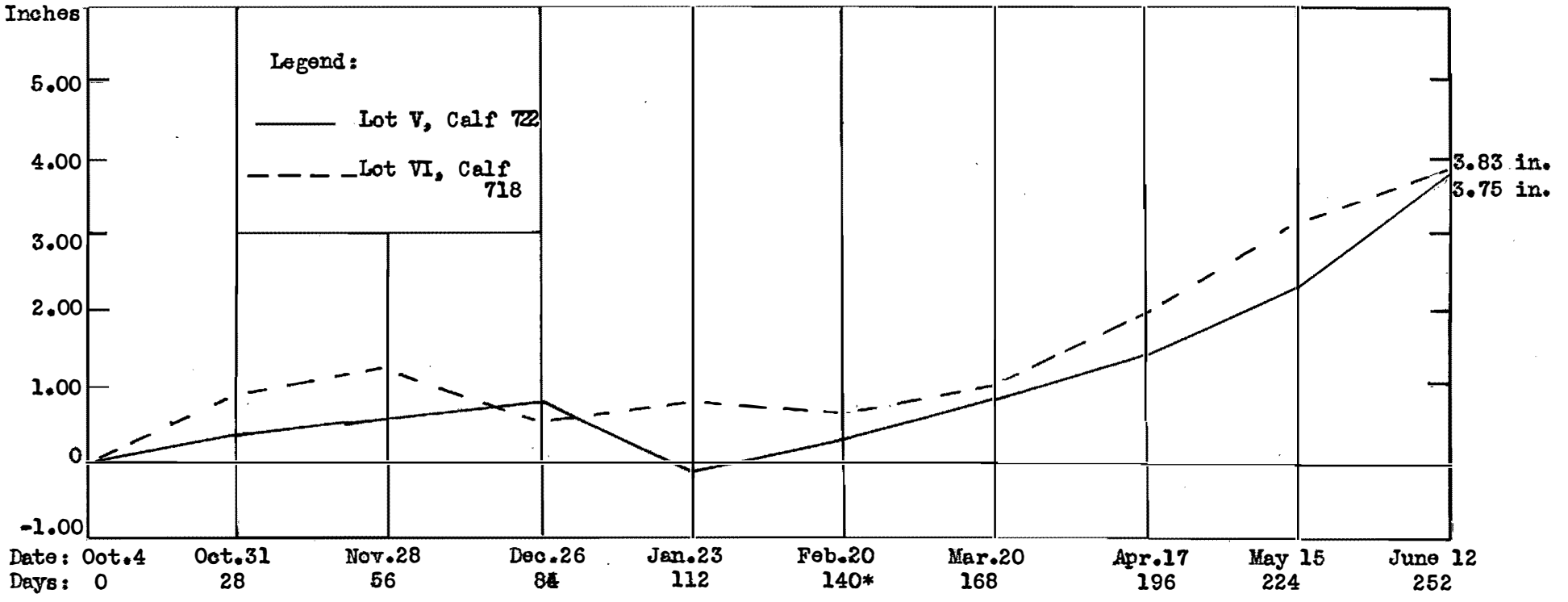


Figure 38. Average gain in weight after phosphorus supplement was added to the ration of Lots V and VI, and both calves put on the same hay. (.16% P.)



*Both calves put on Lot V ration, plus 10 gm. P. a day.

Figure 39. Gain in height by 28-day periods of Lots V and VI



*Both calves put on Lot V ration, plus 10 gm. P. a day.

Figure 40. Gain in heart girth of Lots V and VI, by 28-day periods

TABLE XX

FEED CONSUMED DURING PRELIMINARY AND 28-DAY PERIODS BY LOT V (Calf 722) and LOT VI (Calf 718) BEFORE AND AFTER THE RATIONS WERE CHANGED

Lot No.	Calf No.		Preliminary (35 da.)	28-day periods					Total & av. 1st 5 periods	28-day periods				Total & av. last 4 periods
				1	2	3	4	5		6[a]	7	8	9	
V	722	Total feed consumed	133.70	165.00	213.75	216.75	161.22	174.65	931.37	205.75	224.00	224.00	224.00	877.75
		Av. daily consumpt.	3.82	5.89	7.63	7.74	5.75	6.23	6.65	7.34	8.00	8.00	8.00	7.83
VI	718	Total feed consumed	110.50	180.00	199.17	201.00	193.54	161.50	935.21	196.70	207.90	224.00	224.00	852.60
		Av. daily consumpt.	3.15	6.43	7.11	7.17	6.91	5.76	6.68	7.02	7.42	8.00	8.00	7.61

a Both calves put on Ration for Lot V (.16% P. hay) plus 10 grams of phosphorus per day. The hay of Lot VI was, therefore, changed from high to medium phosphorus hay. There was no change of hay for Lot V.

TABLE XXI

INORGANIC PHOSPHORUS OF THE BLOOD IN MG. PER 100 CC. OF WHOLE BLOOD AND THE AVERAGE DAILY FEED PHOSPHORUS IN GRAMS, BEFORE AND AFTER ADDING PHOSPHORUS SUPPLEMENT

Lot No.	Calf No.		Days						Av. 1st 5 per.	Days				Av. last 4 periods
			Beg.	28	56	84	112	140		168[A]	196	224	252	
V	722	Food (gms.)	3.6	5.5	6.6	7.0	5.1	5.5	5.9	16.5	19.1	19.1	19.1	18.4
		Blood (mg.)	4.44	7.78	6.29	5.99	5.48	4.75	6.05	6.03	5.39	6.05	7.12	7.67
VI	718	Food (gms.)	3.0	7.4	7.9	8.2	7.9	6.6	7.6	18.0	18.4	19.1	19.1	18.6
		Blood (mg.)	3.89	5.85	6.08	4.04	5.15	4.42	5.11	5.85	5.37	6.50	6.52	6.06

A. Both calves placed on Ration 5 plus 10 grams of phosphorus daily.

The blood calcium average for both calves was normal and practically the same. Table XXI shows the feed phosphorus and blood phosphorus averages by periods and Table XXII shows the blood calcium averages at various times during the experiment.

Pictures and Observations

Three different dates were used to make pictures. Both Calves 722 (Lot V) and 718 (Lot VI) seem to exhibit more outward appearances of good health at the start of the experiment than on January 23. In the pictures taken in January, the general appearance is not as indicative of a good growing, thrifty condition, as at the start. However, the pictures taken at the close of the experiment indicate that the calves were in a thrifty "good growing" shape again.

After being on the experimental ration approximately a month, Calf 722 went "off feed". He was given tonic and sunshine treatments for several days, after which time he exhibited more eagerness to eat; but he still would not lick his trough clean. It was not until the phosphorus supplement was added to his ration that he would lick his trough clean.

Lots V and VI were the first lots to start eating dirt. They made the largest holes of any of the other calves, and apparently ate more dirt. While he was sick, Calf 722's fecal droppings were usually too loose. Until the end of the experiment he continued to eat dirt, but his craving for it was not so pronounced at the finish. Throughout the experiment, he ate the wood shavings used for bedding.

The appetite of Calf 718 (Lot VI) was only fair at the start of

TABLE XXII

BLOOD CALCIUM IN MG. PER 100 CC. OF BLOOD PLASMA, FOR CALVES 722 and 718 AT VARIOUS TIMES

Lot No.	Calf No.	Periods during experiment				Average of all tests since preliminary
		Preliminary	Beginning	112 days	196 days	
V	722	8.42	9.84	8.91	9.22	9.32
VI	718	9.29	9.45	9.20	9.38	9.34

the experiment. He was a very slow eater. At first, in place of eating his food he would gnaw on his trough. After nearly 20 days on the experimental ration, he developed an abnormal appetite. When the feeder started to unfasten him, Calf 718 would grab his clothes and try to eat them. He would still gnaw on the trough and eat wood shavings, apparently attempting to satisfy his appetite. After nearly a month on the experimental ration, he started being in an exceptionally big hurry to drink some water after each meal, even though his trough was not licked clean. This behavior continued, with his appetite growing slightly worse until his ration was changed. He would lick his stall mate's trough but not his own. About the tenth of January, Calf 718's right eye was observed to be running and swollen. This was well in about a week. A few days later, twenty-six warbles were removed from his back. About the first of February, Calf 718's craving for dirt became pronounced. All through the experiment he ate the wood shavings, which were used for bedding. As soon as the ration was changed, he started exhibiting more pep and started having a keener appetite . At the end of the experiment, his appetite and fecal droppings were normal. The fecal droppings were very loose at times during the early periods of the experiment.

The pictures of Calves 722 (Lot V) and 718 (Lot VI) are shown on the following pages.

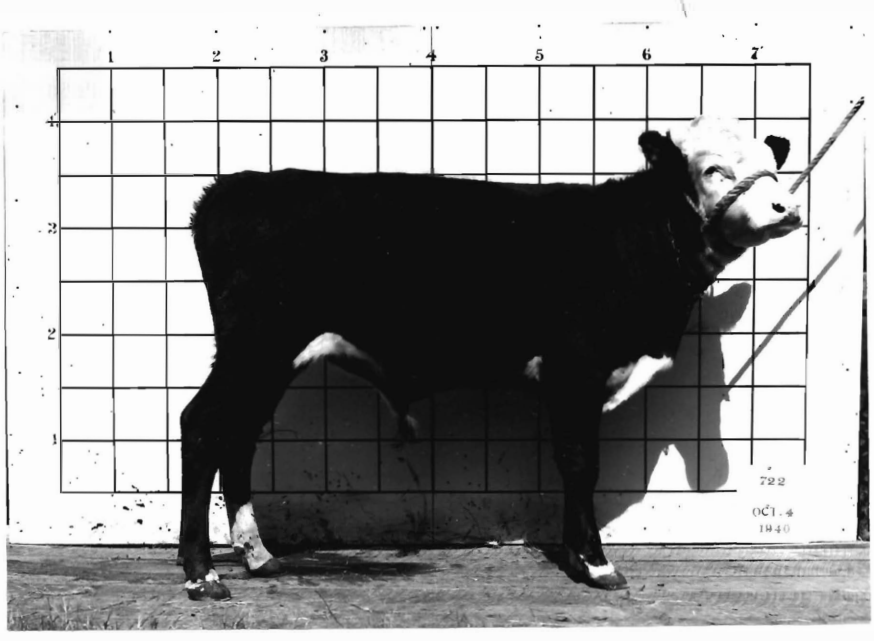


Figure 41. Calf 722 (Lot V) at the start of the experiment

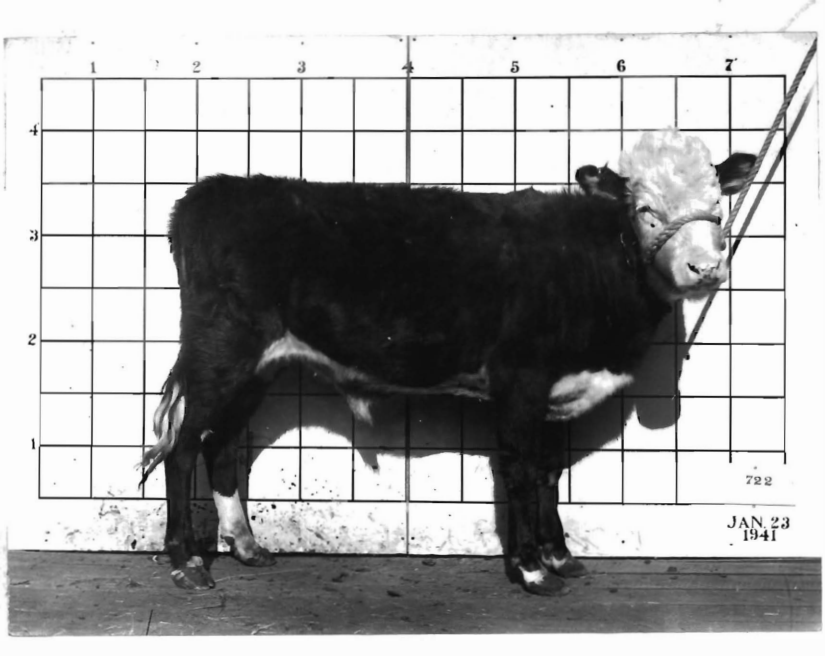


Figure 42. Calf 722 (Lot V) after 112 days feeding

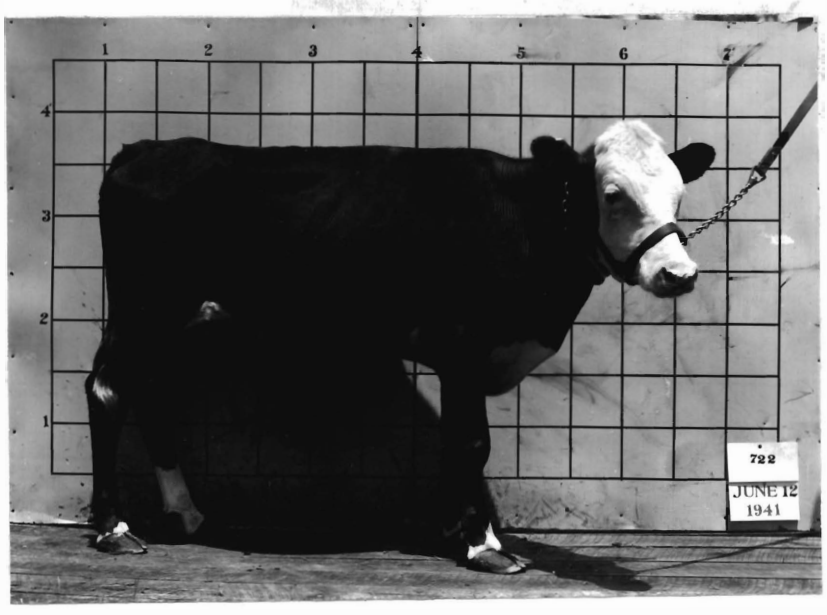


Figure 43. Calf 722 at the end of the experiment and after having had a phosphorus supplement added to his ration the last 112 days of the experiment

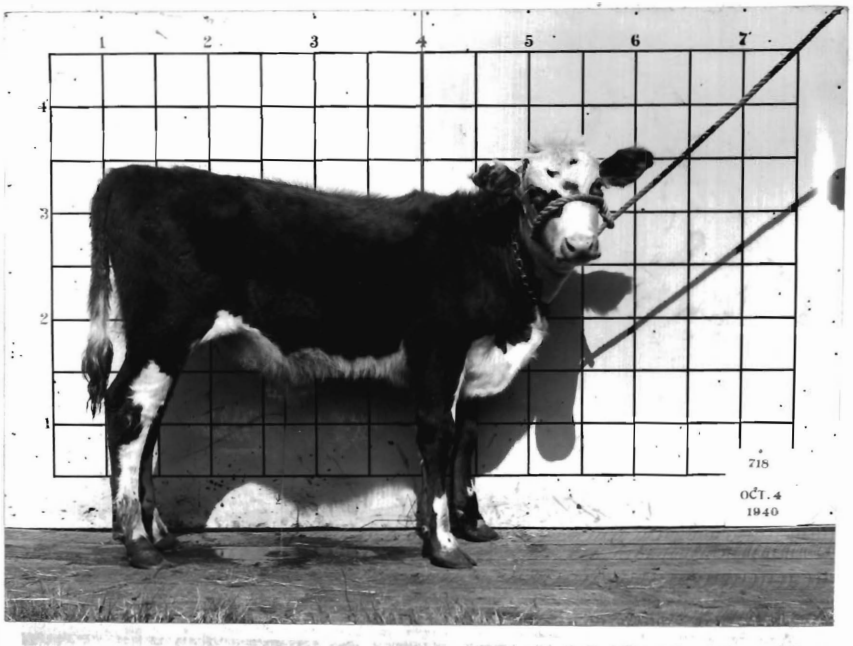


Figure 44. Calf 718 (Lot VI) at the start of the experiment

Figure 45. Calf 718 (Lot VI) after 112 days feeding

Figure 46. Calf 718 at the end of the experiment, the last 112 days being on Ration 5 plus a phosphorus supplement

PART V

RESULTS AND DISCUSSION OF CALF 198

Calf 198 was removed from Lot II because he did not make any gains and could not be gotten on feed during the first five periods. For the last four periods, he was changed to Ration 1 plus 10 grams of phosphorus daily.

Weights and Body Measurements

After 140 days of feeding on Ration 2, Calf 198 weighed two pounds less than he did to start with. However, he had gained in height 1.59 of an inch during this 140 days, even though his increase in heart girth was only 0.18 of an inch. During the last four periods, his average daily gain was nearly .93 of a pound; his increase in height and heart girth, by periods, was .72 and 1.2 inches respectively. These gains are shown in Table XXIII, and graphically in Figures 47, 48, and 49.

Feed Consumed

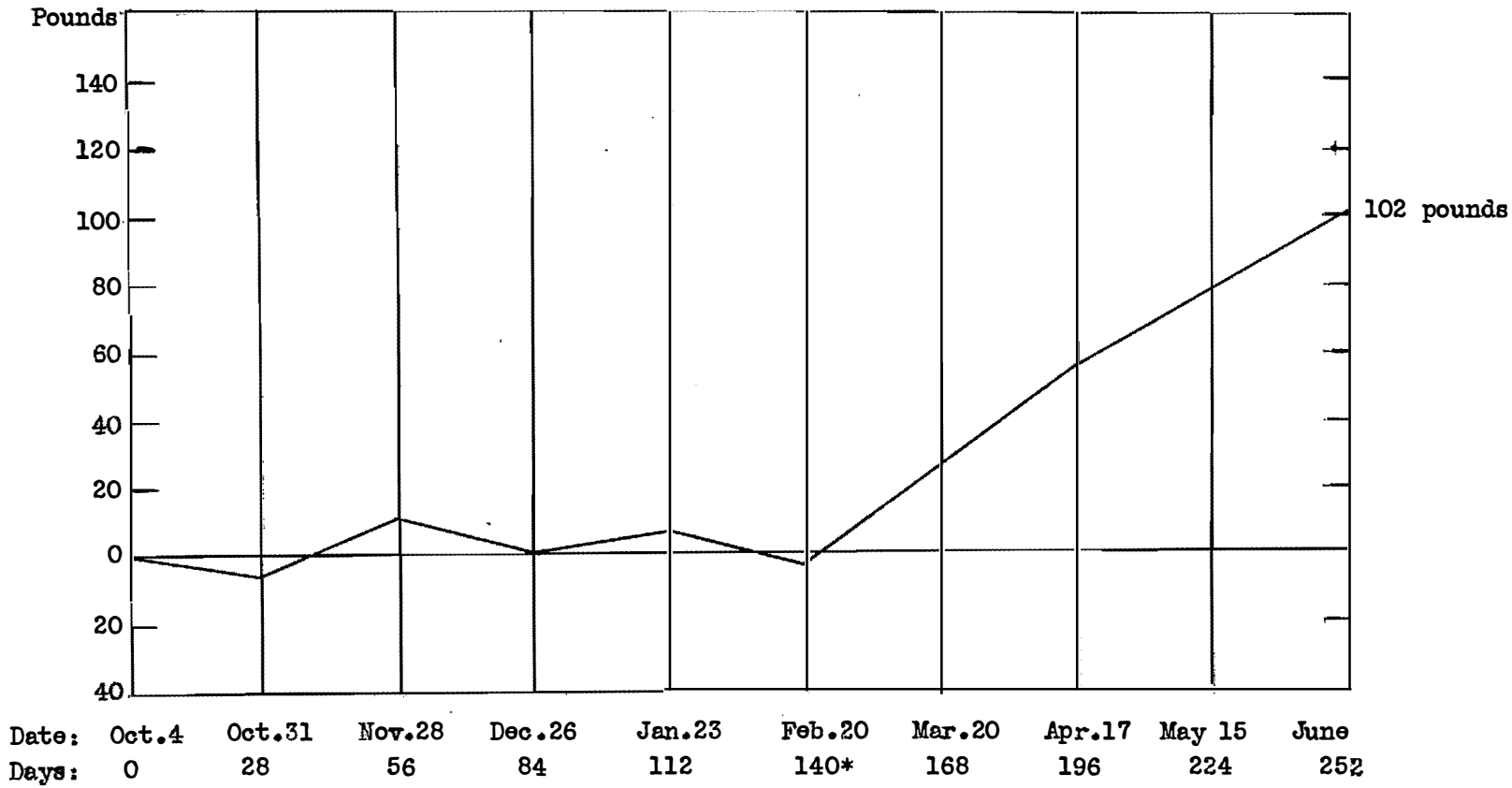
Calf 198 was placed on high-phosphorus hay, corn meal, cod liver oil, and salt (Ration 2) at the start of the experiment. The average daily feed consumption was 5.68 pounds daily for the first five periods. For the entire 252 days, it was the lowest of any calf in the experiment, yet after being on the changed ration for one period, the average daily consumption was increased to 8 pounds a day and remained at that level for the duration of the test, or the last three periods. The feed fed for

TABLE XXIII

GAIN IN HEART GIRTH, HEIGHT, AND WEIGHT BY 28-DAY PERIODS OF CALF 198, BEFORE AND AFTER CHANGE IN RATION

Period (28 days)	Gain in heart girth (inches)	Gain in height (Inches)	Gain in weight (pounds)
1	-0.67	0.50	-4
2	0.25	-0.08	17
3	0.05	0.13	-10
4	0.29	0.70	5
5	0.26	0.34	-10
Total first five periods	0.18	1.59	-2
Average first five periods	0.036	.318	-0.4
6[a]	0.90	0.66	29
7	1.42	0.25	32
8	1.33	1.00	19
9	1.17	1.00	24
Total last four periods	4.82	2.91	104
Average last four periods	1.205	.727	26
Total for nine periods	5.00	4.50	102
Average for nine periods	.55	.50	11.3
Average daily gain	.019	.017	.404

a - Calf 198 placed on Ration 1 plus 10 grams of phosphorus daily.



*10gm. P./day added to the ration (placed on ration I)

Figure 47. Gain in weight of Calf 198, by 28-day periods.
Changed after 140 days from Ration 2 to Ration 1
plus 10 grams of phosphorus daily

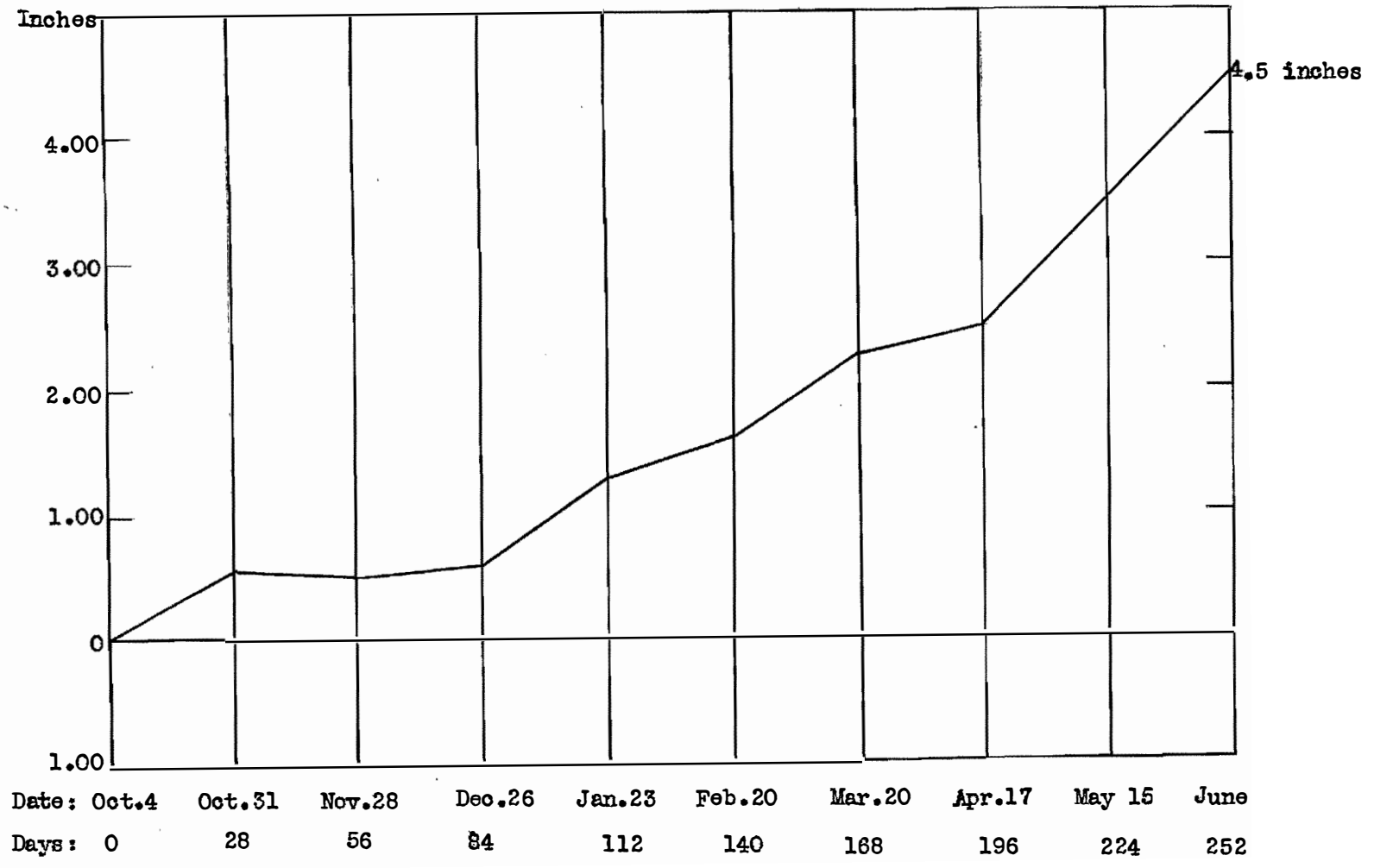


Figure 48. Gain in height of calf 198, by 28-day periods.

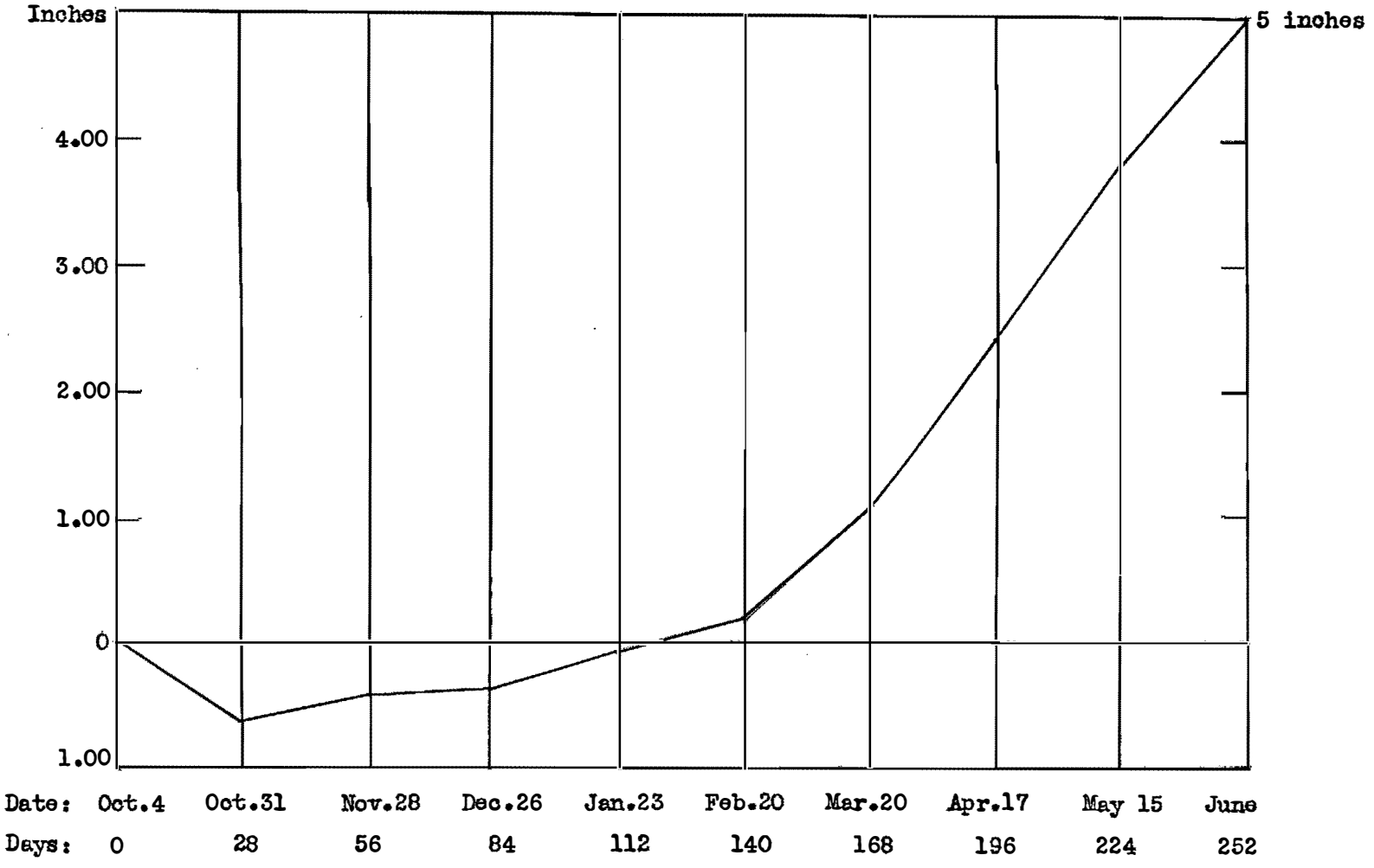


Figure 49. Gain in heart girth of Calf 198, by 28-day periods.

the last four periods consisted of average phosphorus hay, corn meal, cod liver oil, salt, or Ration 1 plus 10 grams of phosphorus daily--fed as Ca H Po_4 (dicalcium phosphate). The feed consumption by periods and the average feed consumption are shown in Table XXIV.

Blood Analyses

The inorganic phosphorus at the beginning of the experiment of Calf 198 was very low and remained below Johnson's[44] standard until this calf was placed on the new ration. After the new ration had been fed for a few days, there was an immediate rise in the inorganic phosphorus of the blood. The inorganic phosphorus of the blood of Calf 198 was 5.4 mgm. when he was placed on Ration 1 plus 10 grams of phosphorus daily. The first week after the change, the inorganic phosphorus of the blood was 7.17 mgm; the second week, 6.83 mgm.; and the third week, 6.97 mgm.

The last 112 days on the new ration constitutes an inorganic phosphorus level of the blood that meets the minimum requirements[44] and in some instances the maximum. The average during the experiment (6.13 mgm.) for Calf 198 is slightly below the mean inorganic phosphorus requirements as stated by Johnson[44].

For the first 140 days, the feed phosphorus level consumed by this calf was below recommended minimum requirements[44]. But for the last 112 days, the feed phosphorus level was above upper minimum requirements. The blood phosphorus is shown in Table XXV.

The calcium average was 8.95 mg. per 100 cc. of blood plasma for the three tests made at the start of the experiment, and on the 112th

TABLE XXIV

FEED CONSUMED DURING PRELIMINARY AND TWENTY-EIGHT DAY PERIODS OF CALF 198, BEFORE AND AFTER A CHANGE IN THE RATION

	Pre-limi-nary 35 da.	28-day periods					Total & av. lst 5 periods	28-day periods				Total & av. last 4 periods
		1	2	3	4	5		6[a]	7	8	9	
Tot l feed co sumed	126.00	102.00	206.50	175.50	169.60	141.10	794.70	214.00	224.00	224.00	224.00	886.00
Average daily consumption	3.60	3.64	7.37	6.26	6.05	5.03	5.68	7.04	8.00	8.00	8.00	7.91

a - Ration changed to Ration 1 plus 10 grams of phosphorus daily, given as Ca H Po_4.

TABLE XXV

INORGANIC PHOSPHORUS OF THE BLOOD IN MG. PER 100 CC. OF WHOLE BLOOD AND THE AVERAGE DAILY FEED PHOSPHORUS CONSUMED IN GRAMS FOR CALF 198

		Days					Av. 1st 5 periods	Days				Av. last 4 periods
	Beg.	28	56	84	112	140		168[a]	196	224	252	
Food (grams)	3.4	4.7	8.4	7.5	7.0	5.9	6.7	17.5	19.3	19.3	19.3	18.8
Blood (mg.)	4.16	6.50	5.64	5.77	4.91	5.40	5.64	6.69	6.16	6.27	7.82	6.73

a - Calf 198 placed on Ration 1 plus 10 grams of phosphorus daily.

end 196th days. During the preliminary period, the blood calcium was higher than at any other period. The blood calcium is shown in Table XXVI.

Pictures and Observations

Pictures of Calf 198 were taken at the start of the experiment, on the 112th day, and at the end of the experiment. Neither of the first two pictures indicate that Calf 198 was very thrifty. However, the pictures show Calf 198 to be in a more thrifty condition at the start of the experiment than after 112 days on the experimental ration. The last picture shows the thrifty condition that Calf 198 had reached at the the close of the experiment.

The first day of the experiment, Calf 198 ate wood shavings in preference to his feed (Ration 2.). His appetite was poor, and he gnawed on wood and the clothing of feeder. Three weeks after the start of the experiment, Calf 198's joints seemed stiff and to creak and pop when he moved about. Sunshine and tonic treatments were administered for nearly a month in an effort to get him to eat. He did fairly well in eating for nearly a month and then went off feed again. Tonic treatments were again given. This was just before his ration was changed; his appetite and fecal droppings were not normal. Improvement was noticed after Calf 198 had been on the new ration (Ration 1 plus 10 grams of phosphorus a day) a week. At the end of the first month on the new ration, Calf 198 had a good appetite and normal fecal droppings. Toward the close of the experiment, this calf continued to eat wood shavings but stopped chewing wood. The general appearance changed to a healthy, thrifty good growing condition.

TABLE XXVI

BLOOD CALCIUM IN MG. PER 100 CC. OF BLOOD PLASMA FOR CALF 198, AT VARIOUS TIMES DURING THE EXPERIMENT

Periods during experiment				Average of all tests after preliminary
preliminary	Beginning	112 days	196 days	
10.58	8.53	9.01	9.33	8.95

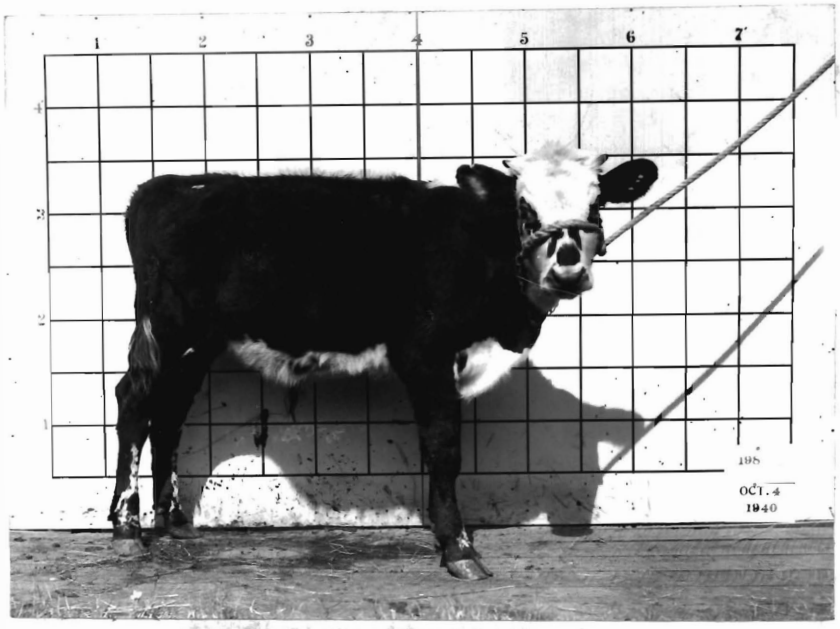


Figure 50. Calf 198 at the start of the experiment

Figure 51. Calf 198 after 112 days on Ration 2

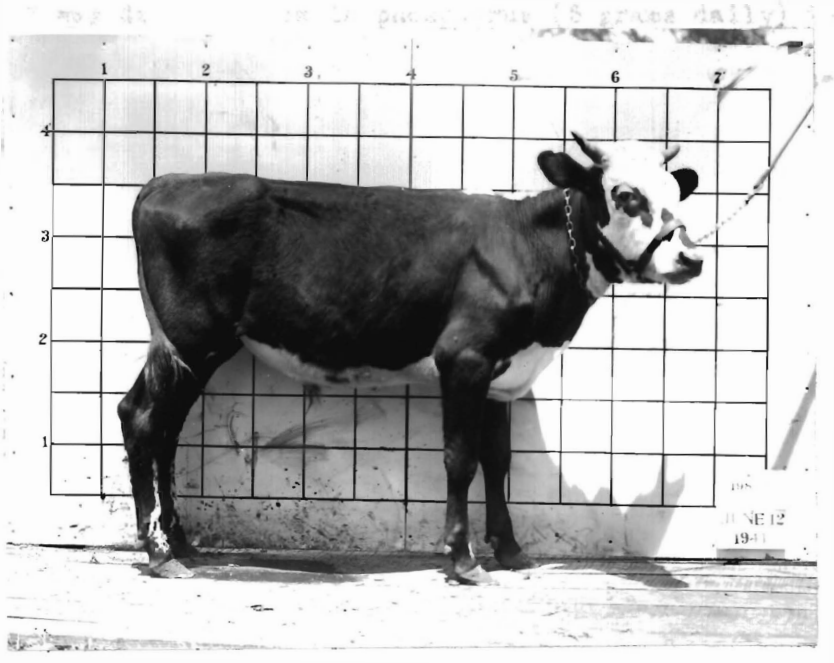


Figure 52. Calf 198 at the end of the experiment. The last 112 days of the experiment he was fed Ration 1 plus 10 grams of phosphorus daily

PART VI

RESULTS AND DISCUSSION OF LOT VII (CALF 721)

Ration 7 was designed low in phosphorus (5 grams daily) in order to study the effects of such a ration supplied with casein. After 140 days, 10 grams of phosphorus daily were added to this ration.

Weights and Body Measurements

Calf 721 gained 1.25 inches in height even though it lost 21 pounds in weight and .75 of an inch in heart girth for the first five periods. The average loss per period in weight was 4.2 pounds during the first 140 days and the gain per period for the last 112 days (after phosphorus was added to the ration) was 27 pounds. The average daily gain for the entire experiment was .34 of a pound, while the average gain per period in height and heart girth was .34 and .37 of an inch respectively. The periodical changes in heart girth, height, and weight are shown in Table XXVII and Figures 53, 54, and 55.

Feed Consumption

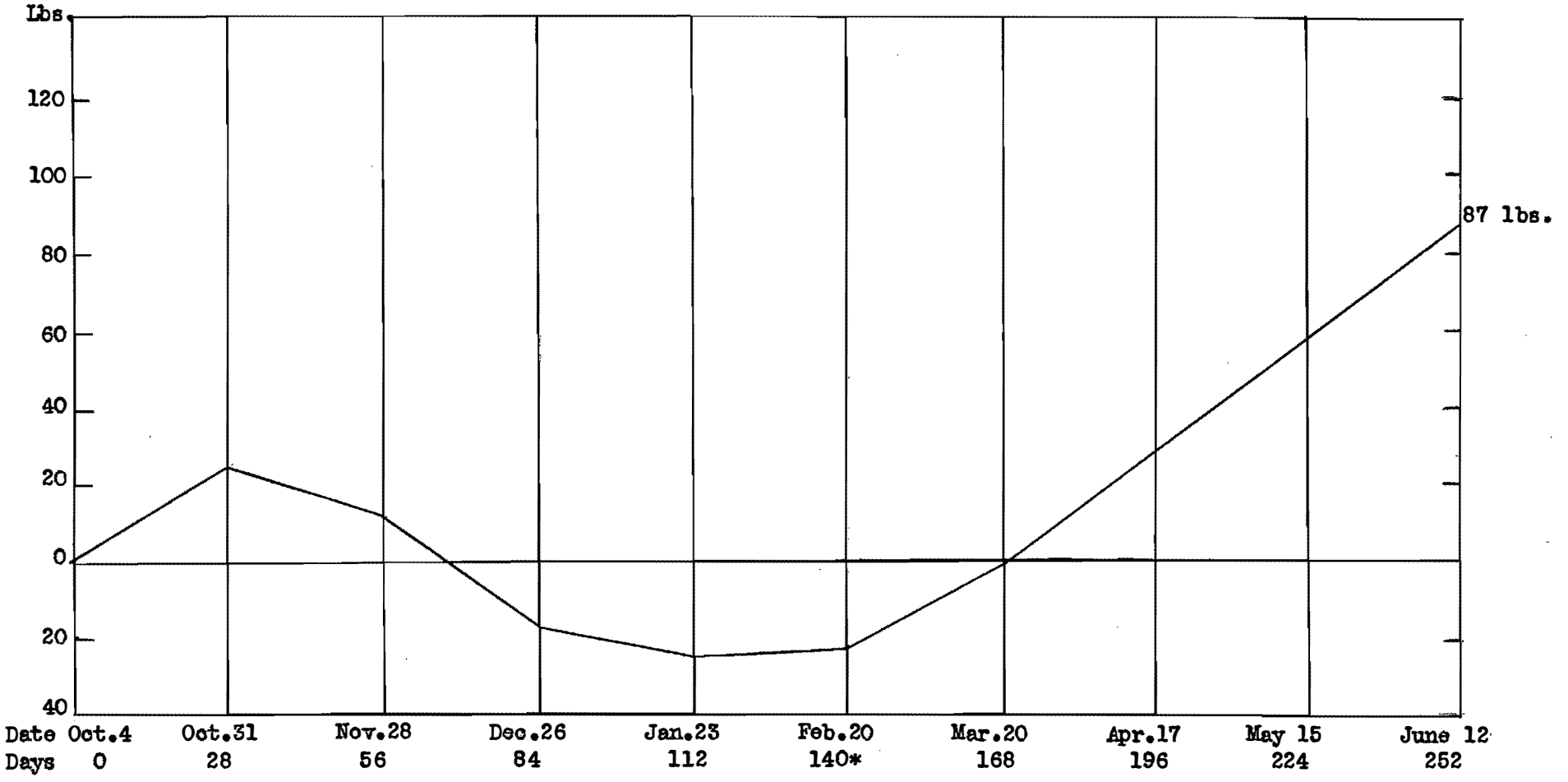
Ration 7 (Calf 721) was set up as the low-phosphorus ration and consisted of (.16% phosphorus) red clover hay, cornstarch, beet pulp, casein, salt, and cod liver oil. It was planned to be definitely low in phosphorus and this ration supplied only 5 grams of phosphorus per day. The average daily feed consumption was low during the first 140 days. However, immediately after Ca H Po_4 was added to the ration, the feed consumption started increasing and continued to increase until the normal

TABLE XXVII

GAIN IN HEART GIRTH, HEIGHT AND WEIGHT BY 28-DAY PERIODS OF CALF 721 BEFORE AND AFTER PHOSPHORUS SUPPLEMENT WAS ADDED TO ITS RATION

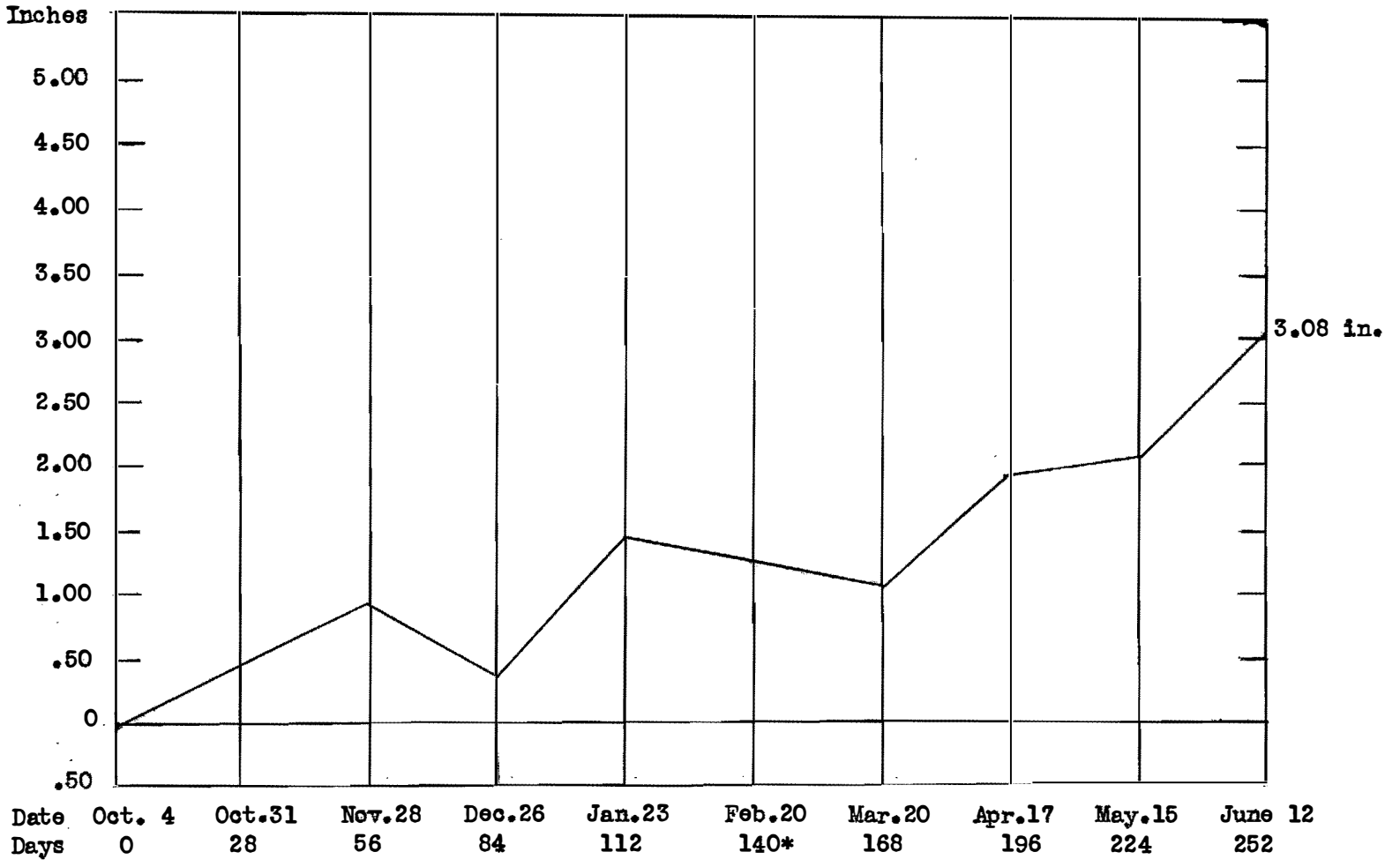
Period (28 days)	Gain in Heart Girth (inches)	Gain in Height (inches)	Gain in Weight (pounds)
1	0.58	0.42	25
2	- .08	0.50	-11
3	- .87	-0.54	-29
4	- .30	1.12	- 7
5	- .08	-0.25	1
Total First 5 Periods	- .75	.1.25	-21
Average First 5 Periods	- .15	.25	- 4.2
6*	0.58	-0.17	23
7	1.25	0.84	29
8	1.34	0.16	28
9	0.91	1.00	28
Total Last 4 Periods	4.08	1.83	108
Average Last 4 Periods	1.02	.457	27
Total 9 Periods	3.33	3.08	87
Average 9 Periods	.37	.342	9.66
Average Daily Gain	.013	.012	.34

*Ten grams of phosphorus in the form of dicalcium phosphate added to its ration at this point.



*Phosphorus added to ration

Figure 53. Gain in weight, by 28-day periods, of Lot VII Calf 721.



*Ration changed by adding phosphorus.

Figure 54. Gain in height, by 28-day periods, of Lot VII Calf 721.

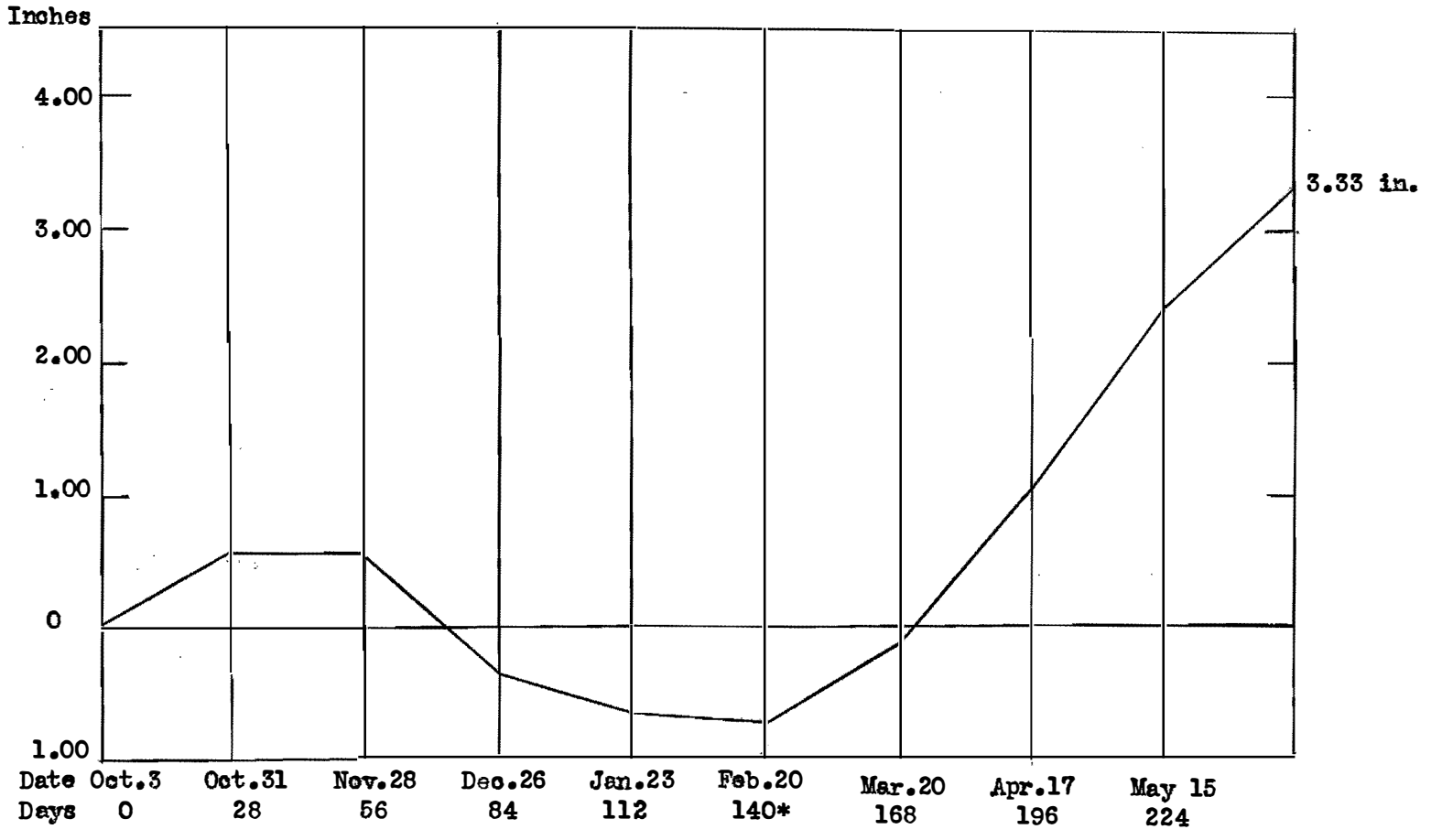


Figure 55. Gain in heart girth, by 28-day periods, of Lot VII Calf 721.

level was reached. The total feed consumed each period and the average daily feed consumptions are shown in Table XXVIII. Table XXIX shows the new ration fed Calf 721 for the last 112 days.

Blood Analyses

Because of the self-imposed starvation the feed phosphorus consumed for the first 140 days is very low and much below requirements(44) as suggested in the early part of this work. The low blood phosphorus content of this calf may have been due to the low-phosphorus content of the feed consumed. The blood phosphorus rose to 6.41 mgm. the first week after phosphorus was added to the ration, 6.97 mgm. the second week, to 6.47 mgm. the third week, and back to 5.56 mgm. the fourth week. This sudden rise in inorganic phosphorus reached the normal limits, according to Johnson(44) and the rise continued during the feeding of the phosphorus supplement.

The blood phosphorus and feed phosphorus consumed is shown in Table XXX.

The blood calcium maintained a fairly uniform level. It was a little low considering the large percentage of calcium in the ration, but it must be remembered that the food consumption was very low when these calcium analyses were made. The calcium analyses are given in Table XXXI.

Pictures and Observations

Pictures of Calf 721 were taken at the same regular intervals as for the other calves perviously discussed. The picture taken in October shows Calf 721 to have a tendency to stand with a bowed back; however, judging from its general appearance and coat of hair, the calf is in a

TABLE XXVIII

FEED CONSUMED BY CALF 721 (RATION 7) DURING PRELIMINARY AND TWENTY-EIGHT PERIODS

	35 days preliminary	28-Day periods										
		1	2	3	4	5	Total & average first 5 periods	6*	7	8	9	Total and av. last 4 periods
Total feed consumed	130.00	177.00	190.20	188.30	170.34	154.09	879.83	198.65	220.15	224.00	224.00	866.80
Av. daily consumption	3.71	6.32	6.79	6.72	6.08	5.50	6.28	7.09	7.86	8.00	8.00	7.74

*Ten grams of phosphorus daily added to ration in the form of Ca H Po_4.

TABLE XXIX

NEW RATION "7" FED TO CALF 721 AFTER 2-21-41

Feed	Percent
Red clover hay (0.16%)	65
Cornstarch	24.16
Beet Pulp	5.0
Casein	3.0
Salt	1.0
Cod Liver Oil	0.5
Ca H Po_4	1.34
Total	100.00

TABLE XXX

INORGANIC PHOSPHORUS OF THE BLOOD, IN MG., PER 100 C.C. OF WHOLE BLOOD AND THE AVERAGE DAILY FEED PHOSPHORUS CONSUMED IN GRAMS BY LOT VII CALF 721

	Days											
	Beginning	28	56	84	112	140	Average First 5 Periods	168*	196	224	252	Average Last 4 Periods
Food (grams)	3.5	4.0	4.2	3.7	3.8	3.4	3.8	14.4	14.9	15.0	15.0	14.8
Blood (mg.)	3.89	3.98	5.80	5.12	4.87	4.46	4.84	5.56	5.43	6.18	6.16	5.83

*Ten grams of phosphorus daily added to the ration.

TABLE XXXI

BLOOD CALCIUM IN MG. PER 100 CC. OF BLOOD PLASMA FOR CALF 721 AT VARIOUS TIMES DURING EXPERIMENT

	Pre-limi-nary	Periods during experiment			Average of all tests after pre-liminary
		Begin-ning	112 days	196 days	
Blood calcium (mg.)	8.75	8.82	9.06	9.45	9.11

fairly good growing condition. The second picture, taken in January, shows Calf 721 to be in poor condition and not in as thrifty a shape as at the start of the experiment. In the last picture the calf has filled out, exhibits much life, seems to be in better condition, and to have made considerable growth during the last four periods. The pictures are shown in Figures 56, 57, and 58.

At the start of the experiment Calf 721 had a fair appetite but was a slow eater. As the experiment progressed, his appetite became worse, his fecal droppings were loose, his joints started popping when he walked, his back became more bowed, and he became very listless and without much pep. At various times he was given a tonic, but this was of no permanent value. He developed pronounced craving for dirt, clay, and wood. Immediately before the ration was changed, he showed definite symptoms of aphosphorosis--that is, stiffness of joints, wood gnawing, craving for dirt. He was listless and had a dull general appearance, and a poor appetite. At the time the ration was changed, Calf 721 weighed twenty-one pounds less than he did at the start of the experiment. Two days after the ration was changed, he started to exhibit a little more pep and to have a keener appetite. From this time on his progress was rapid, his appetite became keen, and he filled out and became normal in all respects. However, he still continued to eat wood shavings even at the end of the experiment.

Figure 56. Calf 721 at the start of the experiment.

Figure 57. Calf 721 (Lot 7) after 112 days feeding.

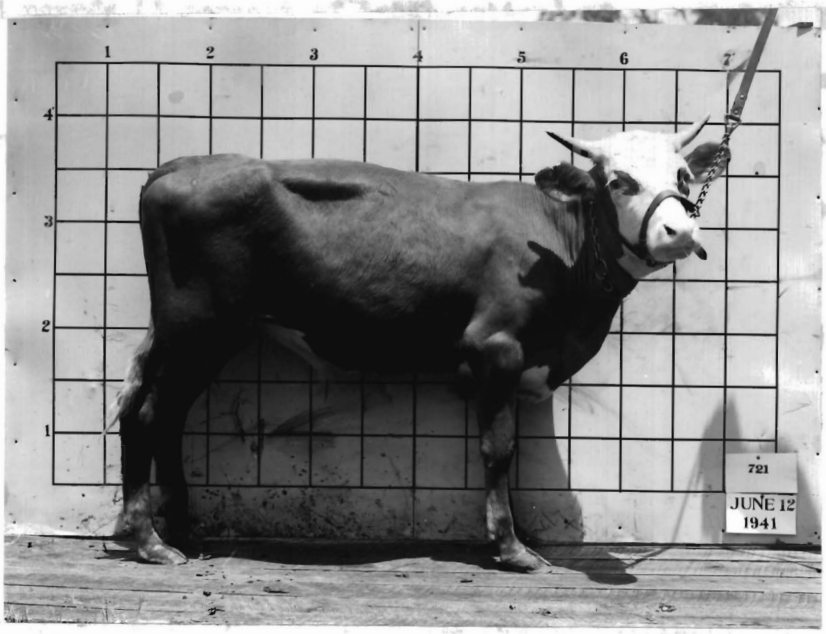


Figure 58. Calf 721 (Lot 7) at the end of the experiment, phosphorus being added to the ration for the last 112 days.

PART VII

RESULTS AND DISCUSSIONS OF LOT VIII (CALF 724)

This Ration (No. 8) was designed to study the effects of the addition of 24 pounds (3 percent of total ration) of a protein supplement (casein) to a ration that supplied the bare minimal level of feed phosphorus (7 grams). There was only one calf in this lot. The other ration with which this one was paired was Ration 7 in which 3 percent of the ration was casein and which supplied 5 grams of phosphorus daily. The behavior of Calf 724 after the first 140 days is discussed in Part III.

Weights and Body Measurements

Calf 724 after being in Lot VIII for 140 days, was removed and substituted for Calf 716 in Lot X. This was deemed advisable because the supply of high phosphorus hay was not sufficient to carry all the calves being fed on this hay and 716 was removed from this experiment for the reasons previously stated. While in Lot VIII Calf 724 averaged 11.4 pounds increase in weight, .68 of an inch increase in heart girth, and .51 of an inch increase in height for the first five periods. The gains are shown in Table XXXII and Figures 61, 62, and 63.

Feed Consumption

Calf 724 gradually increased in its feed consumption as the experiment progressed until it reached the maximum level of nearly eight pounds daily after the first 56 days. It had an average daily feed consumption of 7.50 pounds for the first five periods. The feed consump-

TABLE XXXII

GAIN IN HEART GIRTH, HEIGHT AND WEIGHT BY 28-DAY PERIODS OF CALF 724 (LOT VIII) BEFORE BEING PLACED IN LOT X

Period (28 Days)	Gain in Heart Girth (inches)	Gain in Height (inches)	Gain in Weight (pounds)
1	0.83	0.59	19
2	-0.58	0.41	- 2
3	0.58	0.05	17
4	1.25	1.20	16
5	1.33	0.34	7
Total First Five Periods	3.41	2.59	57
Avg. First Five Periods	.68	.518	11.4

tion is shown in Table XXXIII.

Blood Analyses

The feed phosphorus consumed by calf 724 during the first 140 days was slightly below the amount proven essential in the previous year's experiment(54). The last reading of the inorganic phosphorus of the blood was slightly below the normal minimum level as suggested by Johnson(44). The blood calcium average for calf 724 was 9.78 mg. per 100 c.c. of blood plasma. The inorganic phosphorus of the blood is shown in Table XXXIV and the blood calcium in Table XXXV.

Pictures and Observations

The pictures of calf 724 were taken at the same time as those previously mentioned for other calves. A study of the two pictures of calf 724 shows him to be in a good growing condition, and to have made some growth.

At the first of the experiment calf 724 was a slow eater with only a fair appetite. During the first month he was off feed continually, but after this first period he maintained a fairly healthy appetite. He ate wood shavings from the start of the experiment and started eating dirt immediately before being changed to ration 10. Pictures of calf 724 (Lot VIII) are shown in Figures 59 and 60.

TABLE XXXIII

FEED CONSUMED DURING PRELIMINARY AND TWENTY-EIGHT DAY PERIODS OF CALF 724 WHILE IN LOT VIII

	Prelim-inary 35 days	28-Day Periods					Total First 5 Periods
		1	2	3	4	5	
Total Feed Consumed	98.16	181.00	203.26	219.20	223.50	224.00	1050.96
Avg. Daily Consumption	2.80	6.46	7.26	7.82	7.98	8.00	7.50

TABLE XXXIV

INORGANIC PHOSPHORUS OF THE BLOOD IN MG. PER 100 C.C. OF WHOLE BLOOD AND THE AVERAGE DAILY FOOD PHOSPHORUS CONSUMED IN GRAMS FOR CALF 724 WHILE IN LOT VIII

	Days						Average After Beginning
	Beginning	28	56	84	112	140	
Food (grams)	2.6	5.7	6.2	6.8	7.0	7.0	6.5
Blood (mg.)	3.94	5.29	6.06	5.42	5.65	5.00	5.48

TABLE XXXV

BLOOD CALCIUM IN MG. PER 100 CC. OF BLOOD PLASMA FOR CALF 724 AT VARIOUS TIMES DURING THE EXPERIMENT

Periods during experiment				
Prelimi-nary	Begin-ning	112 days	196 days	Average of all tests since pre-liminary
8.32	9.70	9.88	9.77	9.78

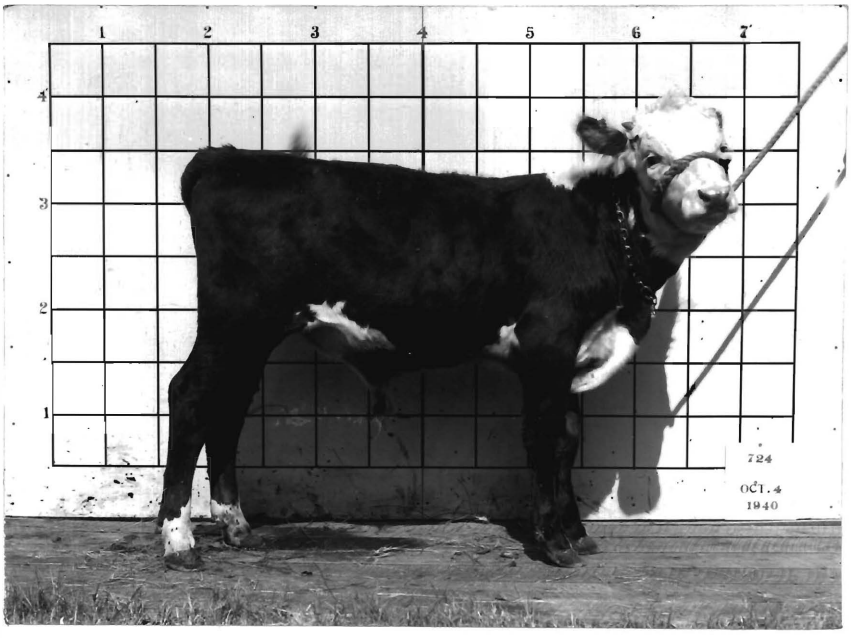


Figure 59. Calf 724 at the start of the experiment

Figure 60. Calf 724 (Lot VIII) after 112 days feeding

PART VIII

RESULTS AND DISCUSSIONS OF CALF 716 AFTER BEING REMOVED FROM LOT X

The performance of calf 716 during the first five periods of the experiment is discussed in Part III. This part consists of a discussion of calf 716 during the last four periods of the experiment after being removed from Lot 10. During the last three periods calf 716 was fed only 31% phosphorus red clover hay that was on hand from the previous year. He was fed this hay in order to see how he would respond to a good quality high phosphorus hay, plus salt, as his only feed.

Weight and Body Measurements

During the sixth period calf 716 lost in height, heart girth and weight. For the last three periods calf 716 averaged one pound a day increase in weight, .80 of an inch in heart girth per period, and .64 of an inch in height per period. The gains are shown in Table XXXVI and Figures 61, 62 and 63.

Feed Consumption

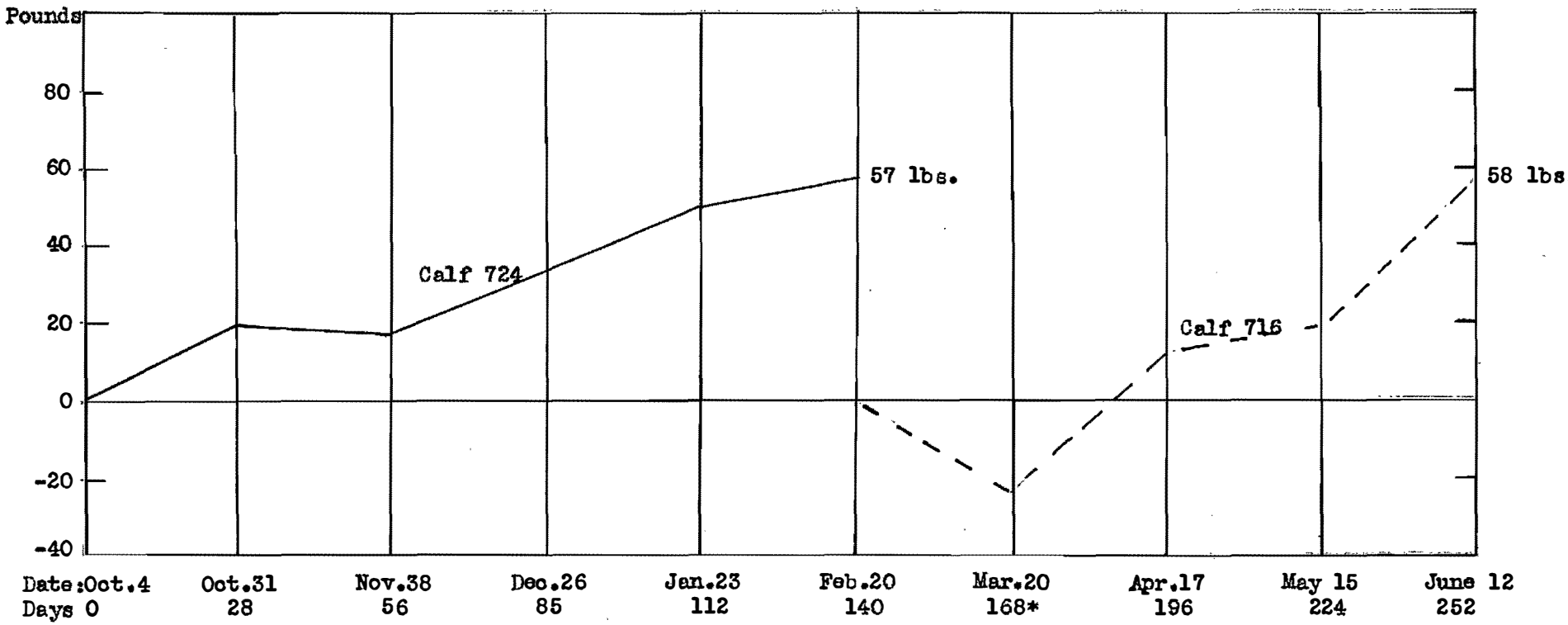
Calf 716 had a good average daily feed consumption barring the sixth period. Even with this period included, calf 716 averaged 7.27 pounds of feed consumed per day during the last four periods. During the sixth period calf 716 received odd lots of feed and then for the last three periods .31% phosphorus red clover hay only. The performance of this calf had been unsatisfactory in Lot 10 and he was removed from that lot. It was decided to see how he would respond to a ration of

TABLE XXXVI

GAIN IN HEART GIRTH, HEIGHT AND WEIGHT BY 28-DAY PERIODS OF CALF 716 AFTER BEING REMOVED FROM LOT X

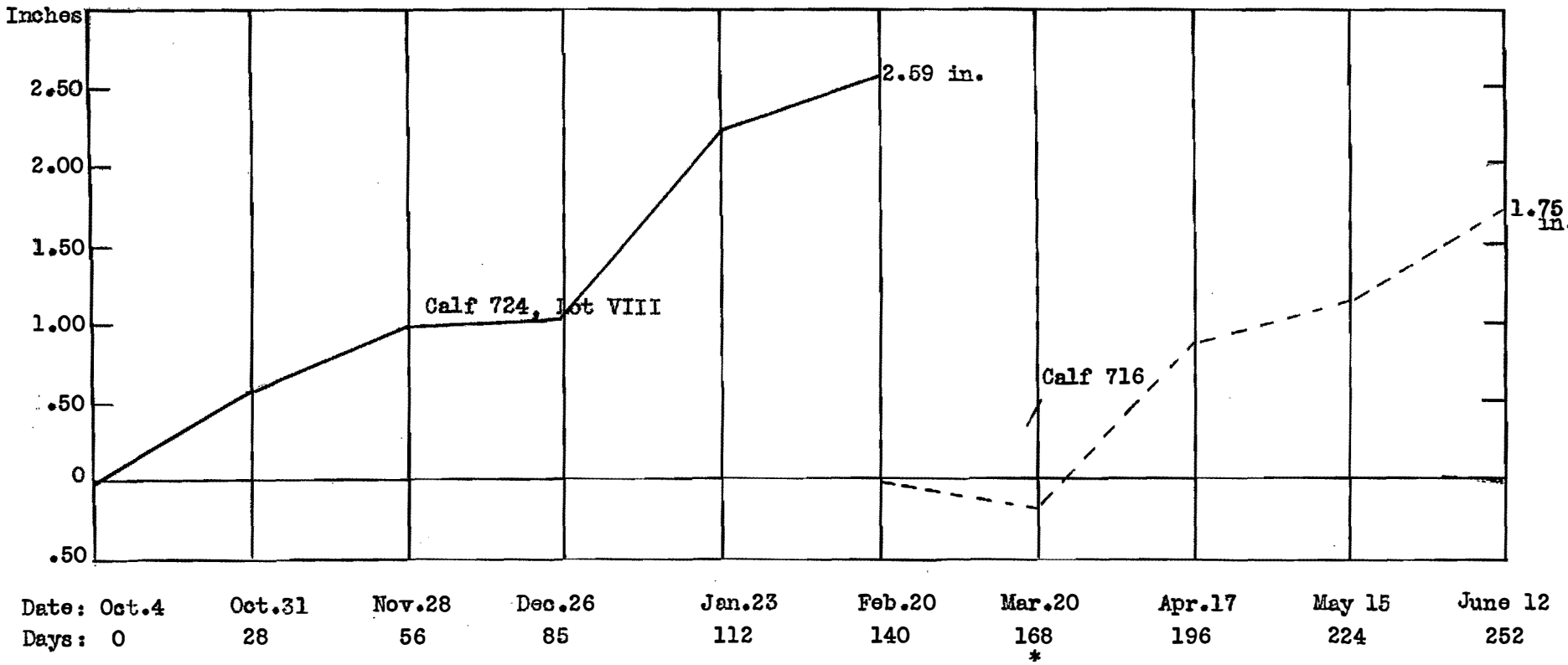
Periods 28 Days	Gain in Heart Girth (inches)	Gain in Height (inches)	Gain in Weight (pounds)
6#	-0.33	- .17	-23
7*	0.50	1.08	39
8	0.66	0.25	6
9	1.25	0.59	39
Total Last 3 Periods	2.41	1.92	84
Average Last 3 Periods	.80	0.64	28

#Odd lots of hay plus a handful of $CaHPo_4$ daily.
*Placed on (.31% P.) red clover hay only.



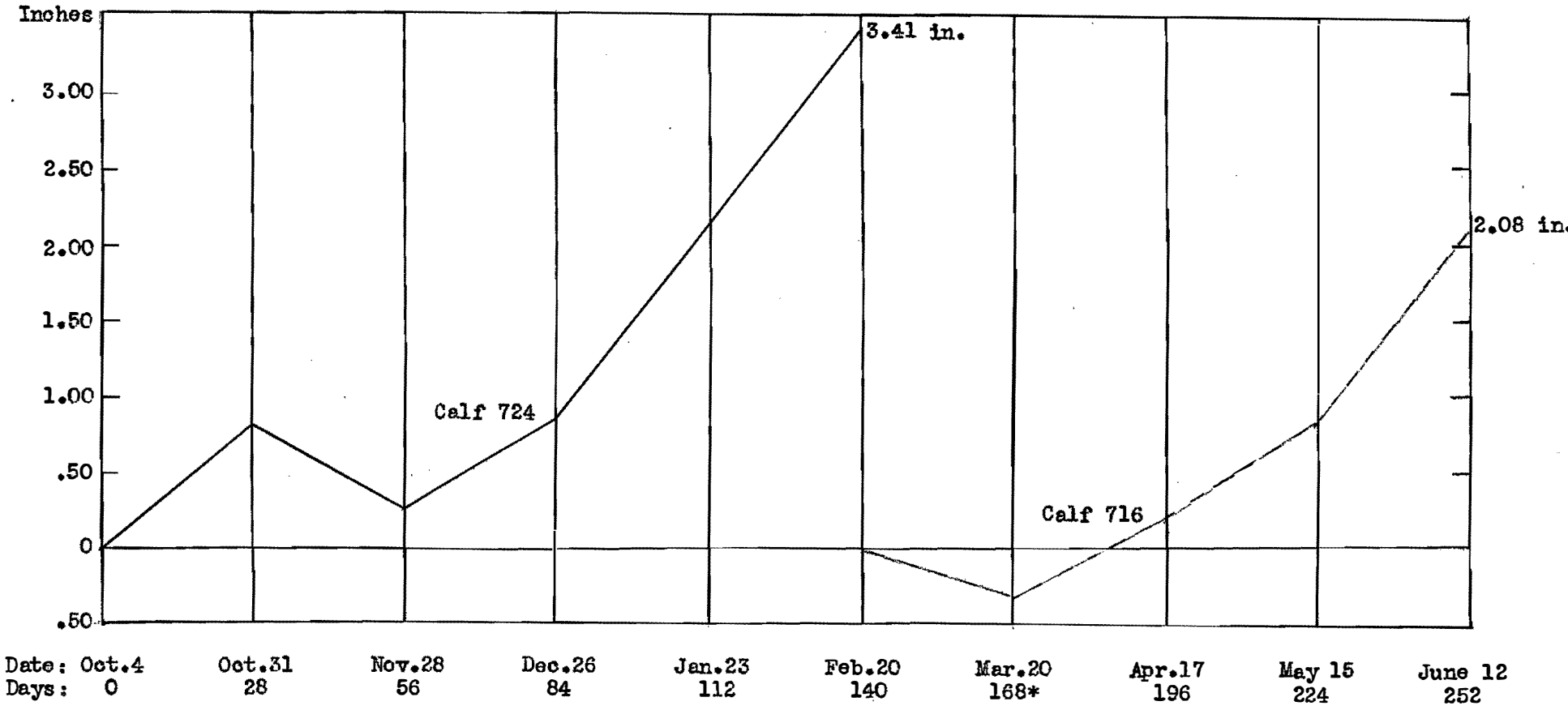
*Feed changed to 0.31% P. Red clover hay alone.

Figure 61. Gain in weight of Calf 724 (Lot VIII) before being placed in Lot X; and of Calf 716 after being removed from Lot X



*Ration changed 0.31% P. Red clover hay alone.

Figure 62. Gain in height of Calf 724 before being placed in Lot X, and of Calf 716 after being removed from Lot X.



*Ration changed to 0.31% P. Red clover hay alone.

Figure 63. Gain in heart girth of Calf 724 (Lot VIII) before being pla ed in Lot X., and of Calf 716 after being removed from Lot X.

hay only. There was some of the high phosphorus hay (.31% P.) used the previous year on hand and this was the hay used. The feed consumption is shown in Table XXXVII.

Blood Analyses

During the last four periods the average daily feed phosphorus consumption was adequate(54) and the inorganic phosphorus of the blood was normal(44). The blood calcium average for calf 716 was 8.79 mg. per 100 c.c. of blood plasma. The inorganic phosphorus of the blood for the last four periods is shown in Table XXXVIII, and the blood calcium is shown in Table XXXIX. The inorganic phosphorus of the blood was not analyzed the first week after his ration was changed, but for the second week the average was 6.85 mgm. and for the third week 5.7 mgm.

Pictures and Observations

Comparing the two pictures of calf 716, we notice that he has made considerable growth and that his general appearance is indicative of a better state of health at the close of the experiment than in January.

During the last three periods calf 716 was consistently improving in appetite and condition. For the time preceeding the last three periods (first 168 days) calf 716 was in a poor state of health. He had developed symptoms of aphosphorosis, that is, he gnawed on wood, had a depraved appetite, ate wood shavings, ate dirt, and had stiff joints. Two days after the feed was changed to .31% phosphorus red clover hay only, the symptoms of a phosphorus deficiency started to disappear and at the end of the experiment had completely disappeared. Pictures of calf 716 are shown in Figures 64 and 65.

TABLE XXXVII

FEED CONSUMED BY CALF 716 THE LAST 112 DAYS OF THE EXPERIMENT

	Periods -- 28 days				Total last 4 periods
	6*	7**	8**	9**	
Total feed consumed	137.20	198.60	220.10	259.00	814.90
Average daily consumption	4.90	7.09	7.86	8.39	7.27

*Fed odd lots of hay plus a handful of Ca H Po_4.
**Fed high phosphorus hay (.31Percent P.) that was on hand from the previous year.

TABLE XXXVIII

INORGANIC PHOSPHORUS OF THE BLOOD IN MG. PER 100 C.C. OF WHOLE BLOOD AND THE AVERAGE DAILY FEED PHOSPHORUS CONSUMED IN GRAMS FOR CALF 716 AFTER BEING REMOVED FROM LOT X

	Days				Average for the 4 Periods
	168*	196⊖	224	252	
Food (grams)	5.7	10.5	11.4	12.96	10.14
Blood (mg.)	6.41	5.67	5.82	6.63	6.13

*Odd lots of hay plus a handful of $CaHPo_4$ daily.
⊖Placed on high phosphorus hay only (.31% P.).

TABLE XXXIX

BLOOD CALCIUM IN MG. PER 100 C.C. OF BLOOD PLASMA FOR CALF 716 AT VARIOUS TIMES DURING THE EXPERIMENT

	Preliminary	Periods During Experiment			Average of all tests Since Preliminary
		Beginning	112 Days	196 Days	
Blood Calcium	8.42	9.38	8.53	8.48	8.79

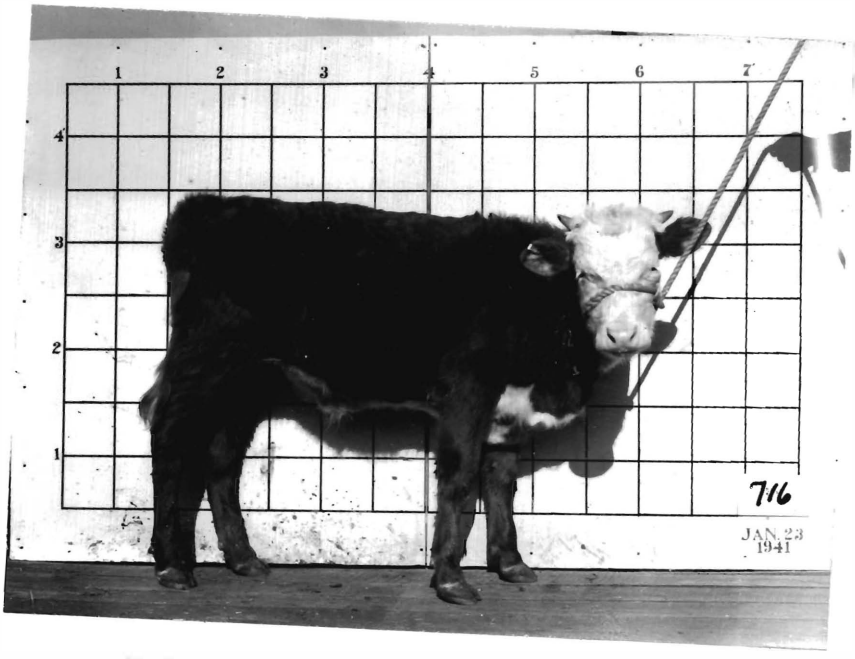


Figure 64. Calf 716 - 28 days before being removed from Lot 10

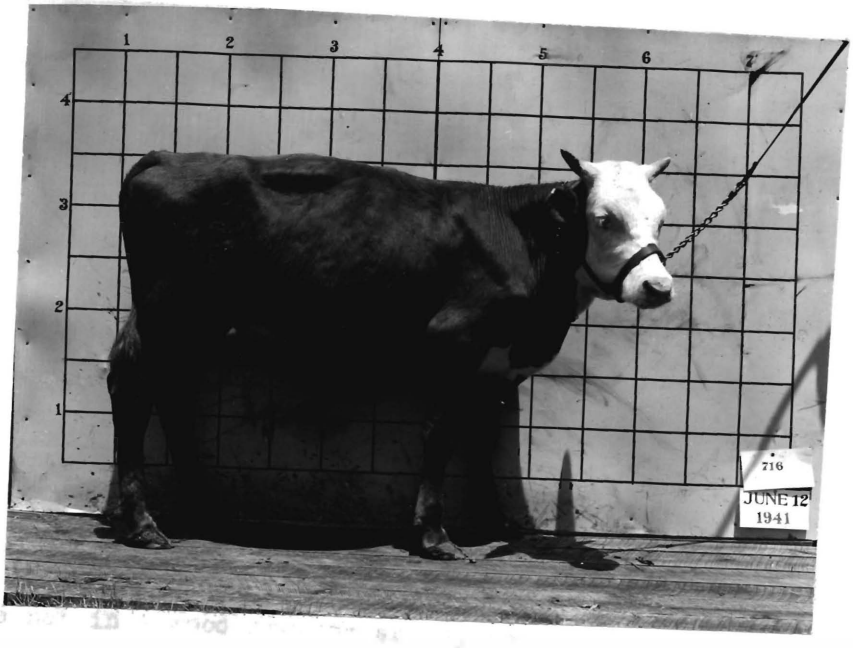


Figure 65. Calf 716 at the end of the experiment; the last 84 days being fed only red clover hay (31% phosphorus)

PART IX

STUDIES OF THE EFFECTS OF ADDING PHOSPHORUS SUPPLEMENTS FOR A SUPPLEMENTRAY PERIOD OF 112 DAYS

After the experiment had run 140 days some changes in the original plan were made. The reason for making the changes were: First, the supply of high phosphorus hay was insufficient to carry all the calves on this hay thru the entire experiment; Second, some of the calves had not responded to the rations and were considered to be of little or no value to the experiment.

The following calves were included in this study:

Calf 198 in Lot 2.

Calf 722 in Lot 5.

Calf 718 in Lot 6.

Calf 721 in Lot 7.

Results and Discussions

Calves 722 and 721 had 10 grams of phosphorus daily added to their rations for the last 112 days. Calf 198 was changed to ration 1 plus 10 grams of phosphorus daily, and calf 718 was changed to ration 5 plus 10 grams of phosphorus daily. Table XXXVI shows that the gains in weight were either very low or negative for the first 140 days and that the inorganic phosphorus of the blood was low(44). Their condition showed that they were not in a good growing shape, and they seemed very listless in general appearance. Calf 721 was definitely suffering from a phosphorus deficiency at the start of this latter period.

During the first week after the rations were changed as listed

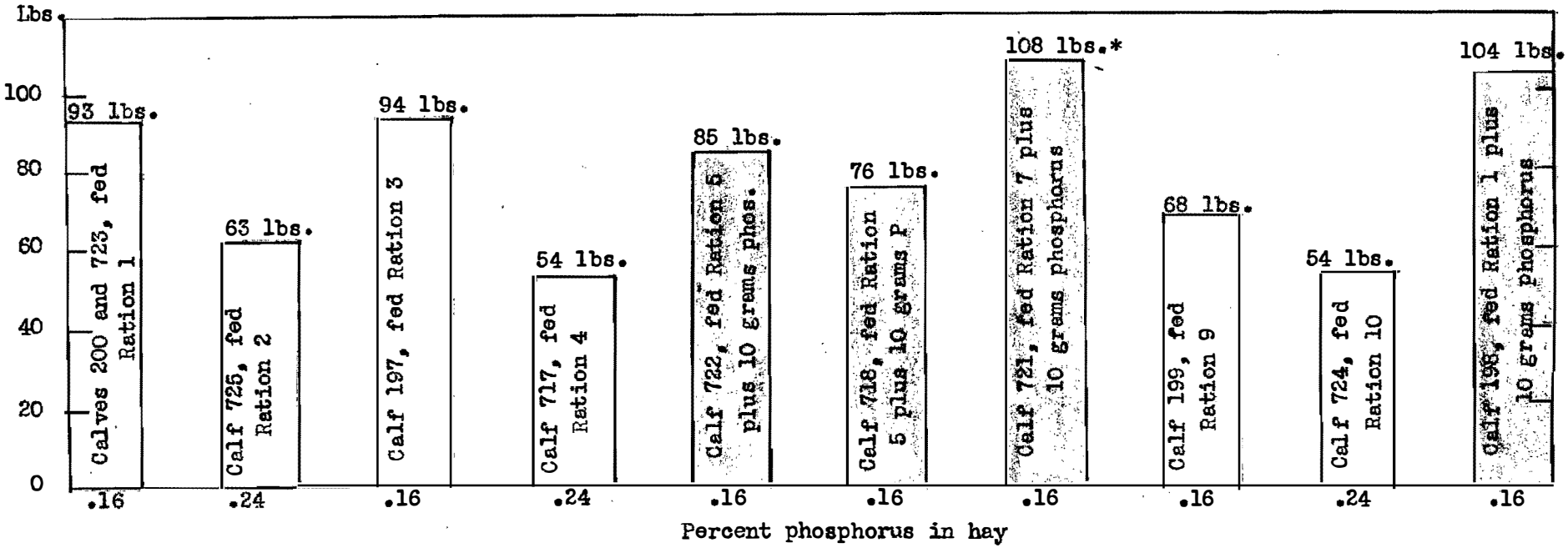
above, all four calves had an increase of appetite, appeared thriftier and to have more pep, started to gaining in weight, and the inorganic phosphorus of the blood rose to a normal[44] level. The total gains in weight for the last 112 days are shown in Figure 66. At the end of the experiment these four calves were all thrifty, had made good gains for this latter period, and had excellent appetites.

TABLE XL

RATION, GAIN, CONDITION OF CALVES 198, 722, 718, AND 721 FOR FIRST 140 DAYS, AND THE PHOSPHORUS OF THE BLOOD ON THE 140TH DAY

No. of Calf	Ration First 140 days	Gain for 1st 140 Days (lbs)	Inorganic Phosphorus of Blood on 140 Day* (mg.)	Condition of Calves
198	Ration 1	-2	5.40	These calves were thin, had a poor appetite, and their fecal droppings were loose much of the time. They were unthrifty, ate the dirt at the edge of their stalls, and gnawed on wood and the clothing of the feeder.
722	Ration 5	7	4.75	
718	Ration 6	8	4.42	
721	Ration 7	-21	4.46	

*Mg. per 100 c.c. of whole blood.



*Calves 198 and 721 were in thin flesh at the start of this period, and therefore were in position to make rapid gains when gains were made.

Legend: Received 15 to 18 grams phosphorus daily

Received 7 to 11 grams of phosphorus daily

Figure 66. Showing the comparative gains of calves receiving 15 to 18 grams of phosphorus daily, with those receiving 7 to 11 grams daily

SUMMARY OF RESULTS

1. The red clover hay used for the low-phosphorus hay in this trial gave consistently better results than the high-phosphorus clover hay. The average superiority in gains in weight in three comparisons was 26 percent. This low-phosphorus hay contained .16 percent phosphorus compared to .12 percent for the previous year. The high hay contained .24 percent phosphorus as compared to .31 percent for the previous year. In the trial last year the high-phosphorus hay gave 31 percent greater gains than the low hay.

2. A hay reasonably rich in phosphorus is not necessarily a satisfactory hay for growing calves. As explained elsewhere, the high-phosphorus hay used in this trial was considered to be less desirable in quality (as regards foreign material) than the low-phosphorus hay. This, and perhaps other undetermined factors, may account for this year's results.

3. The .16 percent phosphorus red clover hay grown on good land and put up in a satisfactory manner was sufficiently rich in phosphorus and other nutrients to support a fair amount of growth in young calves (.68 pounds daily gain), as fed in this experiment.

4. The addition of 2 grams of phosphorus in the form of dicalcium phosphate to the basal rations of Lots I and II for Lots III and IV did not give any significant improvement in rate of gain, growth, or blood phosphorus, the gains being 183 and 117 pounds for Lots I and II,

and 170 and 127 pounds for Lots III and IV.

5. Cornstarch, beet pulp, and cottonseed meal when substituted in the rations for corn meal and 8-percent of the hay did not give as good results as basal Rations 1 and 2. The gains for 140 days were 7 and 8 pounds for the two lots receiving the above, as compared to 80 and 54 pounds on the lots receiving the basal rations.

6. That an adequate supply of phosphorus is essential for growth and health is shown by the performance of the calf in Lot VII. This calf, consuming only 4 grams of phosphorus per day for the first 140 days, lost 20 pounds in weight and showed marked symptoms of malnutrition.

7. The feeding of large amounts of phosphorus supplement (15 to 19 grams daily) to certain undernourished calves during the supplementary period of 112 days brought about a quick improvement in appetite, gains, and blood phosphorus. The total gains during the period however, were not significantly greater than for the calves in Lot I receiving 7.2 grams of phosphorus daily. In some instances the addition of the phosphorus supplement was accompanied by a change in the hay in the ration.

8. The use of casein in these trials in Rations 7, 8, 9, and 10 apparently did not improve the performance of the calves in these lots. However, during the first five periods there was an indication that the use of casein and a phosphorus supplement for the calf in Lot IX might be beneficial. This calf gained 12 pounds more than the

best gaining calf in Lot I during this first period, but more than lost this advantage during the rest of the trial, the final gains of these calves being 181 for Lot IX and 201 pounds for Calf 200 in Lot I.

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